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ABSTRACT

This paper developed methodology to assist school principals in determining the existence of potential indoor air pollution problems and how to alleviate them, as well as a procedure for pollution prevention. Site visits were conducted on 10 South Carolina elementary schools: five with high potential for indoor air pollution; five with low potential. Site visits revealed the principals of all 10 schools had little knowledge about indoor air pollution problems, and little understanding of the operation and maintenance of their buildings and support systems. Study findings suggest that only when principals become aware of the causes of air pollution, the problems it can create, and its prevention, should they get involved in the diagnostic, alleviation or prevention activities. The study isolates climate control and ventilation as two primary areas of concern which need to be addressed to avoid wasting time and resources. Proper maintenance was found to be the best preventive activity for indoor air pollution problems, and the one most often cut during budgetary restrictions. Appendices provide the survey form used in the study, copies of correspondence, and the manual entitled, "The Diagnosis, Alleviation, and Prevention of Indoor Air Pollution in School Buildings: A Manual for School Administrators." (Contains 82 references.) (GR)

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THE DEVELOPMENT OF A SYSTEMATIC PROCESS FOR ENHANCING THE AWARENESS OF THE POTENTIAL FOR INDOOR AIR POLLUTION IN SCHOOLS

Roger William Liska

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ROGER WILLIAM LISKA
The Development of a Systematic Process for Enhancing the Awareness of the Potential for Indoor Air Pollution in Schools
(Under the direction of KENNETH TANNER)

The major objective of this dissertation was to develop a document, based on the findings from this study, which provides the school principal with a process of determining if there exists potential problems with indoor air pollution, and, if so, how to alleviate them. Furthermore, the document presents a procedure to assist the user in preventing indoor air pollution.

Six hundred and fifty of the 816 elementary schools in South Carolina were surveyed using a specially designed form to provide a basis from which to select schools for further study. From those returning the survey, ten schools were selected. Five of which had a high potential and five had a low potential for indoor air pollution.

The methodology, including formats and recommended instrumentation, used in each of the ten site visits was incorporated into the final document from this study for the diagnosis of indoor air pollution. The information derived from the literature search and related activities served as the basis for information contained in the document on how to alleviate and prevent indoor air contamination.

During the site visits it was found that little was known about indoor air pollution by the ten principals. The same was true about their understanding of the operation and maintenance of their buildings and the support systems. This finding only reinforced the need for not only the document from this study but also more formal education in these deficient areas.

INDEX WORDS: Indoor Air Pollution, Diagnosing Indoor Air Pollution, Alleviating Indoor Air Pollution, Preventing Indoor Air Pollution, Climatic Factors, Indoor Air Quality, Awareness of Indoor Air Pollution, School Buildings, Principals, Temperature, Relative Humidity.

THE DEVELOPMENT OF A SYSTEMATIC PROCESS FOR ENHANCING THE AWARENESS OF THE POTENTIAL FOR INDOOR AIR POLLUTION IN SCHOOLS

by

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Chapter One

Introduction To The Problem

One of the more important goals of an effective school should be to create and maintain a safe, healthy, and comfortable physical environment in order to maximize the effectiveness of the teaching and learning processes. There are many factors which affect the classroom environment. Some of the major ones are the type and intensity of lighting, temperature, relative humidity and quality of the air. Much is known about the effects of heating, cooling, ventilating and lighting on the teaching and learning processes. However, very little is known about the effects of indoor air quality.

Most people think that air pollution is primarily an outdoor problem (Wesolowski, 1984, Yocum, 1982). But many are not aware that it can be an indoor problem as well. The advent of energy-conserving practices and devices, the use of new synthetic materials and substances, new building design methods and reduced maintenance budgets have, in many cases, reduced the quality of indoor air. This has the effect of producing acute and chronic illnesses of many of the occupants of the affected building(s) (Godish, 1986).

Prior to 1973 very little was known about the health-related effects of indoor air pollution. Because the average person spends about 90% of his or her time indoors (Turiel, 1985, p. 3), researchers believed there was a need to find out exactly how the many contaminants affected the health of the building's occupants. Research was accelerated in this area in the early seventies.

The majority of the studies that have been performed to date relate mainly to office and residential buildings. There has been very little research done in educational facilities and that which has been done involves schools located in foreign countries where buildings and support systems differ from those in this country.

If the findings from research performed on office and residential buildings can be extended to educational facilities, it appears from the research cited in Chapter Two that indoor air pollution has the potential of:

1. Causing acute upper respiratory illness resulting in increased absenteeism of students, teachers, and staff.

2. Hindering the teaching/learning process that takes place in the classroom because of shorter attention spans and a high rate of irritability among students and teachers.

3. Influencing the productivity of those working in the facility such as secretaries and custodial personnel.

4. Decreasing the efficiency and effectiveness of the air distribution system within the building.

5. Decreasing the expected life-time of the materials and support systems from which the building is constructed.

Statement of the Problem

Wherever it occurs, poor indoor air quality is caused by contaminants which have deleterious health-related effects on the occupants of the building. Air contaminants come into contact with the skin and eyes. In addition, they are inhaled and less frequently ingested. They may be absorbed into the body through the skin, respiratory tract and gastrointestinal tract, and are transported throughout the body. After coming into contact with susceptible tissue, some contaminants produce adverse health effects such as irritation of the eyes and mucous membranes, interference with metabolic processes, changes in cell development, and cancer (Salisbury, 1986).

The technology of determining the health-related effect of a specific concentration of one or more pollutants on a certain individual is in its infancy. There are literally thousands of chemical and biological compounds which are considered potential contaminants and whose health-related effects are unknown. A specific air pollutant may produce various health effects in different people and at different times, depending on its chemical and/or biological properties, its concentration, the length of exposure to the contaminant and the sensitivity of the person.

The problem of attempting to diagnose whether or not indoor air pollution is causing illness among the building's occupants is further compounded by the assessment techniques used. A complete evaluation of the environment requires interviewing those having health-related symptoms such as headaches and the sampling and/or monitoring of the air for the type(s) and concentration(s) of air contaminants. Interviews do not always result in obtaining factual information. This is especially the case when the person being interviewed is experiencing conflict within the organization and realizes the power he has in knowing that by giving inaccurate information he or she may be able to get changes made which would alleviate the situation (Nagda, Rector & Koontz, 1987). In addition, many of the symptoms which may occur as a result of being exposed to one or more air contaminants are similar to those resulting from common diseases such as colds and inadequate indoor climate conditions such as unacceptable air exchange rates (Salisbury, 1986). Furthermore, sampling and monitoring of the air may be a very expensive undertaking. Finally, instrumentation does not presently exist to measure very low concentrations of one or a combination of pollutants that may be causing health-related problems (Carlton-Foss, 1983). In summary, there are literally hundreds of variables which may play a major role in determining if a specific concentration of a specific pollutant is causing health-related problems with one individual. And, much is not known about some of the variables. The fact remains that all children, teachers, and school personnel must be provided with an environment which is free from hazardous concentrations of indoor air contaminants.

It is the responsibility of both the school district personnel and local school building administrator to provide and maintain indoor air which is free from pollution. But it is the school building administrator or principal who is held accountable for this responsibility in most school systems. Therefore, it is important that he or she be made aware of the potential health-related problem of indoor air pollution, how to diagnose it, and if it exists, how to alleviate it, and how to prevent it. Presently, there is a lack of understandable and usable information on the subject. A need exists for an effective and efficient method that can be used by the school building administrator to diagnose whether poor indoor air quality is causing illness in one or more of the building's occupants, what the cause is, and how to alleviate it.

Objectives

Major Objective

The major objective of this dissertation is to develop a document, based on the findings from this study, which provides the school principal with: (1) a process of determining if there exists potential problems with indoor air pollution, and, if so, how to alleviate them; and (2) a procedure to prevent the occurrence of indoor air contamination.

Subsidiary Objectives

1. Present a case analysis for schools from which qualitative-based conclusions will be developed which will

serve as data to be included in the development of the final document of this study.

2. Develop, field test, and finalize survey forms which will be used as part of the final document produced for this study.

3. Take physical measurements of temperature, humidity, carbon dioxide, and the contaminant radon in the ten selected schools and the pollutant formaldehyde in five of the ten schools as part of the field test site process, using the appropriate instrumentation and monitoring devices that are readily available to the principal.

4. Determine the level of awareness of indoor air pollution among the principals of the ten case study schools.

5. Develop a process which could be used to diagnose and alleviate health-related problems from indoor air pollution for schools buildings.

6. Identify information which can be used in the development of guidelines for the prevention of indoor air pollution in school buildings.

7. Increase the reader's awareness of the subject of indoor air pollution in school buildings.

8. Suggest areas of the subject that need further study.

Definition of Terms

ACH--Abbreviation for "air changes per hour," a unit of air exchange rate.

Adsorption--Removal of contaminants from the air by soaking them into a material.

Active Monitoring Device--Monitoring equipment which requires an external source of power to operate.

Acute--Category of illness caused by indoor air pollution which will cause death.

Absorption--Removal of contaminants from the air by their retention on the surface of a material.

Air Cleaner--A device designed to remove airborne pollutants such as dust and smoke.

Air Exchange Rate--Amount of air that flows into or out of a building in a specified amount of time.

Air-To-Air Heat Exchangers--Mechanical ventilation devices which can be used to conserve energy.

Aldehydes--Series of organic-based compounds containing -CHO groups and having strong odors.

Allergens--A diverse group of substances that cause allergic reactions.

Allergic--Highly susceptible to a substance that does not produce harmful health effects in a majority of the population.

Ambient Air--That portion of the air that is external to the building.

Analyzer Monitoring Device--Monitoring device which also analyzes the sample being monitored along with providing the results of the analysis.

ASHRAE--Abbreviation for "American Society of Heating, Refrigerating and Air Conditioning Engineers."

Building Envelope--The exterior surfaces such as walls, floor and roof which enclose a building.

Carbon Dioxide--Colorless, odorless gas that is the product of metabolic activity and combustion.

Carbon Monoxide--Colorless, odorless gas that is the product of incomplete combustion process.

CFM--Abbreviation for "cubic feet per minute."

Charcoal Canister--A passive monitoring device for radon.

Chronic--Category of illness from indoor air pollution that continues to exist over a relatively long period of time (depending on type of pollutant) and if not alleviated will result in acute illness.

Ci--Abbreviation for "Curie," a unit of radioactivity equal to 37 billion disintegrations per second.

Clearance Rate--Time it takes for the body to get rid of a pollutant.

Collector Monitoring Device--A type of monitoring device that only collects a sample of air. It must then be sent to a laboratory for analysis.

Concentration--Amount of contaminant in a given volume of air.

Conduction--Movement of heat through a material by molecular vibration.

Contaminant--Substance in the air that is not normally present or that is present in greater-than-normal concentration.

Contaminant Free--Hazardous concentrations of indoor air contaminants do not exist in the environment.

Convection--Movement of fluids (gases and liquids) in response to differences in density caused by temperature differences.

Criteria Pollutants--Pollutants for which there exists national acceptable standards.

Depletion--To reduce the concentration of a pollutant.

Detoxification--To remove toxic substances from the body.

Diffusion--Spontaneous scattering of particles throughout the air from areas of high concentration to areas of low concentration.

Dispersion--Movement of contaminants throughout the air by dispersion and mixing.

Dose--Quantity of a substance absorbed in a part of the body or in an individual.

Electronic Digital Hygrometer--A battery-operated device which measures temperature and relative humidity.

Electrostatic Interaction--Mutual attraction of materials that have opposite electrical charges.

Electrostatic Precipitation--Removal of particles from the air by attracting them to charged materials.

Emission Rate--Amount of contaminant released into the air by a source in a specified amount of time.

Encapsulation--Covering of an object with a film or coating to prevent release of air contaminants from the object.

EPA--Abbreviation for "Environmental Protection Agency," the federal agency responsible for setting and enforcing ambient air quality standards.

Epidemiology--The study of disease as it spreads and involves large groups of people.

Exfiltration--Uncontrolled movement of air out of a building through cracks in the building envelope.

Filtration--Removal of particles from the air by passing the air through a material that screens out the particles.

Forced Ventilation--Ventilation induced by use of mechanical equipment such as exhaust fans.

Formaldehyde--Common air contaminant emitted from many synthetic materials.

µg/m3--Abbreviation for "microgram per cubic meter," a measure of mass per unit volume.

Hypersensitive--High susceptibility to a substance that does not produce harmful health effects in a majority of the population.

Impervious--Impenetrable.

Indicator Tubes--Chemically treated glass tubes which discolor when exposed to a specific pollutant.

Infectious Agents--Bacteria, viruses, and microorganisms that cause human disease.

Infiltration--Uncontrolled movement of air into a building through cracks in the building envelope.

Inhalable Particles--Particles that are not filtered out by the nose and that are deposited along the respiratory tract.

Insecticide--A chemical compound or substance used to kill insects.

Make-up Air--Outdoor air, sometimes called fresh air.

Mass-Balance Approach--Method of studying the change in concentrations of contaminants in the air by measuring rates of contaminant emission and removal.

Mechanical Filtration--Filtering of air by the use of mechanical equipment such as electronic air filters.

Mechanical Ventilation--Forced movement of air by fans into and out of a building.

Mitigation--Removing air pollutants.

Mixing--Redistribution of particles by movement of air.

Natural Ventilation--Movement of air into and out of a building through openings in the building envelope.

NIOSH--Abbreviation for the "National Institute of Occupational Safety and Health."

Noncriteria Pollutants--Pollutants for which there does not exist nationally-accepted standards.

Organic Compounds--Substances which contain carbon.

Outgas--Emission of gases during the aging and degradation of a material.

Passive Monitoring Device--Monitoring equipment which does not need an external source of power to operate.

pCi/L--Abbreviation for "picocuries per liter of air," a measurement of radon concentration.

Permeability--A characteristic of a material which relates to the flow of gasses or liquids through it.

Pesticide--Chemical compound or substances which is used to control rodents and insects.

Plating--Settling out of particles onto a material.

Pollutant--Contaminant present in a concentration high enough to cause adverse effects to health or the environment.

Pollution--The occurrence of one or more contaminants in concentrations high enough to cause adverse effects to health or the environment.

Pollutant-Free--See Contaminant-Free.

PM--Abbreviation for "parts per million," a unit of concentration.

Radon--Chemically inert gas that undergoes radioactive decay by emission of an alpha particle.

Radon Daughters--A series of radioactive elements that result from the radioactive decay of radon.

Radon Progeny--Series of elements that result from the radioactive decay of radon.

Removal Mechanism--Object or process that removes contaminants from the air.

Removal Rate--Amount of contaminant removed from the air by a removal mechanism per unit of time.

Respirable Particles--Particles that penetrate to the lungs when inhaled.

Sensidyne Gastec Pump--A brand name of a pump used with indicator tubes to measure concentrations of certain pollutants.

Spot Ventilation--Mechanical ventilation located at a specific place such as an exhaust fan over a gas stove.

Suspended Particles--Particles so small that they remain in the air and settle out slowly under the force of gravity.

Threshold Level--Concentration above which one's health is affected by a specific contaminant.

Toxic--Capability of a substance to produce a harmful health effect after physical contact, ingestion, or inhalation.

Toxicology--Study of the health-related affects of toxic substances.

Ventilation--Controlled movement of air into and out of a building.

WL--Abbreviation for "working level," a unit of radon progeny concentration.

Working Level--Unit of radon progeny concentration.

Overview

This chapter introduced the problem of this dissertation along with the purpose, major and subsidiary objectives and definition of terms. Chapter Two contains a comprehensive review of the literature on the subject of indoor air pollution and its health-related effects on the occupants of buildings in which contaminants exist. It is beyond the scope of this study to present a detailed description of all the pollutants. However, since radon and formaldehyde are being considered as the "typical indoor contaminants" for this research, they will be discussed in-depth. The information in Chapter Two provides the reader with a thorough understanding on the topic.

Chapter Three presents the methodology used in this study. Chapter Four discusses the findings of the research and finally, Chapter Five presents a summary of the dissertation, interpretation of findings, limitations and implications of the study, and areas for further research. The final product of this dissertation is a document entitled Guidelines for the Diagnosis, Alleviation, and Prevention of Indoor Air Pollution: A Manual for School Administrators, and is contained in Appendix G.

Chapter Two

Review of Related Literature

This chapter presents the results of a literature search on the subject of indoor air pollution and its health-related effects. The purpose of the search was to identify the major variables that needed to be considered in this study along with obtaining the most up-to-date technology and findings on the subject.

The literature search resulted in very few references relating directly to school buildings. Most of the research involved office and residential buildings. However, in most cases, the pollutants and sources that were found to be causing the health-related problems can also be found in educational facilities.

The first section of this chapter introduces the subject matter. It contains an historical overview of the research on indoor air pollution. Before one can take action to alleviate the cause(s) of indoor air contaminants, one must be aware of the many types and their various sources. This information is presented in the second section. The third section of this chapter presents the factors which are known to effect indoor air quality. The variables which determine whether a person's health is affected by one or more contaminants are discussed in the fourth section. Also presented is a review of the various known illnesses caused by indoor air pollutants. The fifth section presents information on the detection and measurement of indoor pollutants. This chapter concludes with a section on the alleviation and prevention of indoor air pollution.

Historic Overview

Until recently when one heard about air pollution, one usually attributed the problem to contaminants in the outdoor or ambient air. Over 150 billion dollars has been spent in the United States in the study and alleviation of pollution of outdoor air (Godish, 1985a, p. 293). The principle reason for the magnitude of this commitment is the protection of public health. The same concern did not exist, until about twenty years ago, with respect to the quality of indoor air.

In the mid-1960s and early 1970s, the focus of air pollution studies turned to indoor environments. Early research on the topic of indoor air quality including that of Biersteken, DeGraaf, and Nass (1965) and Yocum, Clink, and Cote (1971), concentrated on contaminants that had previously been measured outdoors, known as "criteria pollutants." They found that the indoor concentrations of criteria pollutants were effected by not only the outdoor level of the pollutants, but also by indoor generation or removal. The awareness that the quality of indoor air was effected by activities and/or materials found within buildings changed the focus of further research to that of indoor sources.

Cote, Wade, and Yocum (1974), Drivas, Simmonds, and Shair (1972), Spedding and Rowland (1970), and others identified many contaminants which were generated indoors. These are known as "non-criteria pollutants." Furthermore they were able to determine various factors which affect the concentration of the pollutants and the levels at which they begin to affect one's health. Of the contaminants being examined as part of this research, radon was first studied as an indoor pollutant in the late 1960s and early 1970s (Lowder, George, Gogolak, and Blay, 1971). The first studies of formaldehyde were performed in Denmark in the early 1970s (Andersen, Lundquist, and Molhave, 1974).

Since most of these and other related studies were relatively narrow in scope, the results did not have a nation-wide implication in terms of health. It was not until the increase in oil prices that the problem of indoor air pollution surfaced as a major concern for the health of building occupants. As the cost of energy needed to heat, cool, ventilate and light facilities increased, so did the methods of designing and constructing buildings and their support systems. Wesolowski (1984) notes that some of the measures taken to conserve energy were to design buildings to be tighter (more energy efficient) and design mechanical systems to reduce the amount of fresh or outdoor air exchange. Up until about 1979 any action taken to reduce the energy utilization in buildings was purely voluntary. In 1979 the United States government imposed regulations on all federal facilities to make them more energy efficient through the Emergency Building Temperature Restrictions (cited in

Carlton-Foss, 1983). Many states adopted these same regulations for their buildings. In addition, a large part of the private sector incorporated the same recommendations into their building operating policies and procedures (Carlton-Foss).

The results of the implementation of the various energy conserving practices and devices was the decrease of ventilation rates and the increase in the concentration of substances within the building to such a level that caused them to have a negative effect on the health of the occupants; that is they became the sources of indoor pollutants. The phenomena resulting from tightening up the building's exterior walls or envelope and decreasing the rate of fresh or makeup air exchange resulting in the creation of indoor air pollution is known as the "tight building syndrome" (Int-Hout, 1984).

During the same period that energy conservation techniques were being implemented, the building industry experienced the increased use of synthetic materials. Studies supported by the National Research Council (1981, chap. 4) found that many of these materials were sources of indoor pollutants. Furthermore, the results of investigations performed by the National Institute of Occupational Safety and Health (NIOSH) (Melius, Wallingford, Keenyslide, and Carpenter, 1984) in various types of buildings, reported to have problems with indoor air pollution, have shown that one of the major problems is the lack of an adequate level of maintenance, especially on the ventilation system. This allows deleterious organisms to grow and be disbursed throughout the building when the system is operating. The implementation of energy conserving techniques, the introduction of synthetic building materials and decreased levels of maintenance combined to increase the reported incidences of indoor air pollution and thus the level of awareness of the public to the problem.

As a result of the increased awareness of indoor pollution, research was undertaken to attempt to determine the causes of the problem (Bruno, 1983, Godish, 1985a, Olsen & Dossing, 1982, Van Der Wal, 1982, Yocum, 1982). The results of much of this research performed in the early 1980s was inconclusive. Reviewing the results of many studies, Carlton-Foss (1983) found that the level of pollution which can cause health-related problems was occasionally found but that often the causes are elusive. He stated that "this is probably because the field work and diagnostic techniques commonly used have been inadequate to define the cause" (p. 38). Another example of the inconclusiveness of research findings was noted by Int-Hout (1984). He indicated that in some studies of buildings where the occupants were experiencing the symptoms of indoor pollution, contaminants were found to exist but in concentrations that were below the levels that were known to cause health-related problems. Int-Hout suggested that either the effect of the combination of the pollutants or some other pollutant that was not measured was causing the problem.

The issue of poor indoor air quality has and continues to receive much attention as scientists (National Research Council, 1981), professional organizations such as the Air Pollution Control Association ("Present and," 1982), environmental and health groups (American Lung Association, 1984a) and the federal government (United States Environmental Protection Agency, 1980) have come to recognize the potential hazards of indoor contaminants. It must be noted, however, that despite accelerating national interest on this topic, public and private organizations have not supported efforts to determine and make the public aware of the seriousness of health risks from indoor air pollution (Kirsch, 1982 & 1986). According to Sexton and Wesolowski (1985, p. 306) some of the reasons which account for this slow response are:

1. The discovery of poor air quality in nonindustrial indoor environments is relatively recent. Thus there is not a sufficient amount of data as to the quality of people exposed, the pattern and severity of exposure and the health-related consequences.

2. The public has not been made adequately aware of the issue, since it has only been recently that the potential health hazards of indoor pollutants have been recognized.

3. Public and private agencies have been reluctant to act with specific guidelines that would result in the development of statutes.

Within the past two years the subject of indoor air pollution has been the theme of conferences held by such organizations as the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) ("Indoor Air Quality," 1987) and the Georgia Institute of Technology. Furthermore, the United States Department of Energy ("Indoor Air Quality Environment," 1987) and national trade associations such as the National Environmental Health Association and Air Pollution Control Association have issued reports and articles on the topic. In the majority of these cases the audience consisted of professionals who work in the area of indoor air pollution and not the general public. One does find, on an infrequent basis, articles published in periodicals ("Cleaning the air," 1986) and newspapers (Echolm, 1986) and pamphlets issued by medical-related organizations (American Lung Association, 1984b) and governmental agencies (Tennessee Valley Authority, 1984) which are for public consumption. These articles, unfortunately, only present brief overviews of the problem and rarely provide the reader with any significant information which he or she may need to ascertain whether or not indoor air pollution is a potential or existing problem within their indoor environment(s). Based on these facts along with the small quantity of useful articles and books being published on the subject, it is safe to conclude that there still exists much to learn about indoor air pollution and its health-related effects.

Types and Sources of Indoor Pollutants

All air contaminants may be classified as a gas, a particle, or a liquid, according to information contained in the Indoor Air Quality Handbook (1982). It states:

Gases exist as individual atoms or molecules and include organic and inorganic compounds. They remain in the air until they are absorbed by a metal, react to form other compounds or condense to form droplets, as water vapor condenses to form fog and rain. (p. 52)

The same source noted that particles are solids or liquids suspended in the air. They are comprised of many substances such as organic and inorganic compounds, dead organic matter and dormant or living organisms. The particles are of various sizes, shapes and composition, all of which determine the health-related effects they can have on a person.

Therefore, organic and some inorganic compounds may exist either as gases or as components of particles, depending on such environmental conditions as humidity, temperature and the existence of other substances in the air. Particles are suspended in gases and therefore, either one or both can have deleterious effects on one's health. This phenomena makes the investigation of indoor air pollution a more complex issue.

Since research on indoor air quality was initiated, hundreds of contaminants have been identified. It is beyond the scope of this dissertation to discuss the physical and chemical attributes of them all. Table 2.1 lists those common pollutants known to cause health-related problems.

Wesolowski (1984) indicated that sources of indoor contaminants can be categorized into two broad areas. The first are those which are generated outdoors and infiltrate indoors. The second group consists of those that are generated indoors as a result of human activities and the emission of toxic substances from building construction materials, systems, furnishings and substances such as duplicating fluids used in the facility. In the latter case, two subgroups of pollutants can be identified. The first are those which come from building materials and substances which can be found in and around buildings such as formaldehyde in particle board or organic compounds in cleaning fluids. The second group are microorganisms which may be found in heating, ventilating and air conditioning systems.

Caruba (1984) presented a series of pollutants that are commonly found in school buildings. These contaminants and their sources are as follows:

1. formaldehyde from tobacco smoke, particle board resins in furniture and paneling, insulation and resins in carpeting, cloth and adhesives.

2. radon from the ground, masonry materials and well water.

Table 2.1. Summary of Common Indoor Pollutants That Cause Health-Related Problems and Their Origination

Origin predominantly outdoors
Lead
Ozone
Pollens
Sulfur dioxide
Origin predominantly indoors
Allergens
Ammonia
Asbestos
Carbon dioxide
Carbon monoxide
Formaldehyde
Microorganisms (including bacteria and other infectious agents)
Organic substances (including aldehydes, hydrocarbons and others)
Radon
Spores (including fungi and molds)

3. asbestos and fiberglass particles from insulation and fire retardants.

4. pesticides and insecticides both inside and outside the building.

5. nitrogen oxides from kitchen appliances.

6. organic chemicals from paints and copiers.

7. microorganisms from people, plants and animals.

8. carbon dioxide from human breathing.

9. allergens from insects and dust.

Table 2.2 contains a summary of the various sources for the pollutants listed. Specific information on formaldehyde and radon is presented below.

Formaldehyde

Formaldehyde is a colorless gas having a strong characteristic odor when it exists in sufficient concentrations (National Research Council, 1981, p. 6). According to Life & Health ("Formaldehyde--A Hazard," 1981), it is one of the most commonly used compounds in industry and can be found in many products. Some of the major uses are:

1. As glue in particle board and plywood.

2. In urea formaldehyde (UF) foam insulation (which has been banned in most states).

3. As a part of the liquid used to make disinfectants, embalming fluids and dyes.

4. As an additive to a substance used to treat material to prevent creasing in some permanent press clothing.

Table 2.2

Sources of Major Indoor Air Contaminants

Source	Contaminant
Sources of indoor air contaminants in the external environment	
Water	Radon
Air	Bacteria Carbon monoxide Hydrocarbons Nitrogen oxides Sulfur dioxide Particles
Soil	Radon
Sources of indoor air contaminants in the building envelope	
Particle Board	Formaldehyde
Urea-formaldehyde foam insulation	Formaldehyde
Paneling	Formaldehyde
Ceiling tile	Formaldehyde
Plywood	Formaldehyde
Concrete	Radon
Gypsum board	Radon
Sources of indoor air contaminants in the environmental control systems	
Evaporative cooling device	Bacteria

(table continues)

Table 2.2

Sources of Major Indoor Air Contaminants

Source	Contaminant
Gas furnace	Carbon monoxide Nitrogen oxides Sulfur dioxide
Electronic air cleaner	Ozone
Humidifier	Bacteria Fungi Benzo-a-pyrene (Organic compound) Particles Organic compounds
Unvented natural gas space heater	Carbon monoxide Nitrogen oxides Particles
Unvented kerosene space heater	Carbon monoxide Nitrogen oxides
Fireplace and woodstove	Carbon monoxide
Sources of indoor air contaminants in the interior structure	
Particle board	Formaldehyde
Ceiling tile	Formaldehyde
Plywood	Formaldehyde
Paint	Hydrocarbons (nonmethane) Mercury vapor

(table continues)

Table 2.2

Sources of Major Indoor Air Contaminants

Source	Contaminant
Sources of indoor air contaminants in the furnishings and appliances	
Dryers which exhaust directly into home	Particles Chemicals from fabric softeners
Carpet	Bacteria Formaldehyde
Gas stove	Carbon monoxide Aldehydes Nitrogen dioxide Nitric oxide Respirable particles
Furniture	Formaldehyde
Insecticide strip	Dichlovos (organic compound)
Water	Radon
Draperies	Formaldehyde
Sources of indoor air contaminants associated with inhabitants	
Human and animal metabolic activity	Infectious agents Allergens Ammonia Organic vapors
Cleaning with ammonia-containing cleaners	Ammonia
Vacuuming carpet	Bacteria

(table continues)

Table 2.2

Sources of Major Indoor Air Contaminants

Source	Contaminant
Cigarettes	Carbon monoxide Respirable particles
Cleaning oven	Hydrocarbon gases (nonmethane)
Polishing furniture	Hydrocarbon gases (nonmethane)
Hobbies and crafts	Organic vapors
Cleaning carpet	Residue from carpet cleaner

Note. From *Indoor Air Quality Handbook* (Sand 82-1773) (p. 28, 31, 33, 37, 39 & 40) United States Department of Energy, 1982, Washington, D.C.

5. As an additive to paper to make it stronger and more resistant to water.

6. In many household products such as some cosmetics, medications, soaps, toothpaste, shampoo, air fresheners, drapes, carpets, spray starches, deodorants, concrete and plaster.

Although formaldehyde is used in a large variety of products, only a few release sufficient quantities of the chemical to significantly contaminate indoor air (Godish, 1985b). The products causing problems include particle board, subflooring, cabinetry, paneling, furniture, medium-density fiberboard and urea-formaldehyde foam insulation. All of these products are manufactured using adhesives comprised of formaldehyde-based synthetic resins.

The indoor concentration of formaldehyde is affected not only by the type and quantity of known sources but also environmental factors such as temperature and humidity. A National Research Council (1981, p. 86) report indicated that formaldehyde emissions increase with increasing temperature and humidity. The same report also noted that the concentration of the pollutant will increase as the rate of air exchange decreases.

Since its discovery as a potential health hazard manufacturers have made changes to the materials used to reduce the amount of formaldehyde in their products. This has been substantiated by recent research (Gammage, 1986).

However, many sources of this pollutant remain in buildings constructed prior to the time of these changes.

Radon

Radon evolves as a gas produced from the radioactive decay of radium which is found in uranium as well as common rocks such as granite and limestone (Smay, 1985). Some areas of the United States have relatively high levels of these types of substances. These areas are located in the New England states, along the eastern side of the Appalachian Mountains in Pennsylvania and Virginia, in Florida and in granite, uranium or other mineral-bearing areas of the West (Hileman, 1983).

The primary sources of radon include soil gas, well water and masonry materials (Godish, 1985a, p. 318). Of these, the one that has the least effect is masonry materials. Godish indicated that these materials only contribute on the average of 10% or less of observed concentrations. He also stated that this percentage will be increased in very energy-efficient buildings.

Soil gas containing radon enters a building through cracks in the foundation, floor drains, building joints and other openings in contact with the soil (Turiel, 1985, p. 34). If a crawl space exists between the soil and floor of the facility, radon enters the building by diffusion or infiltration (Rundo, Markin, and Plondke, 1979).

The other major source, well water in contact with radon-containing materials, becomes contaminated with radon and enters the building as it is pumped from wells. About half the radon is released to the indoor air when the water is heated, agitated or aerated (Prichard, 1978, McGregor and Gourgun, 1980). The other portion stays in solution.

After entering the indoor air by one of these pathways, radon decays to produce other radioactive elements called radon progeny. The progeny are solids which become attached to air borne particles and when inhaled are deposited along the respiratory tract (Schery, 1986 and Hager, 1985).

Factors Affecting Indoor Air Quality

The quality of indoor air depends on many factors. The major ones include the outdoor concentration of one or more pollutants, the existence of indoor sources of pollutants, the rate of exchange of outdoor air for indoor air, the volume of space within a structure and characteristics of pollutants (Nagda, Rector, and Koontz, 1987, chap. 3). To complicate the issue, these factors must be considered simultaneously. It is important when selecting a means of monitoring and alleviating one or more indoor contaminants that these factors be considered.

Outdoor Concentration of Pollutants

When discussing indoor pollutants, one must consider the existing relationship of the quality of indoor-to-outdoor air. Yocum (1982) presents a number of factors that must be considered about the indoor-to-outdoor air quality when discussing the existence and concentration of indoor pollutants. These are as follows:

1. outdoor air quality--Indoor air quality will respond to changes in outdoor air quality. The magnitude of the response will depend on the nature of the pollutant and its concentration along with the other factors presented in the balance of this list.

2. pollution depletion mechanisms--These methods include atmospheric conversion of the pollutant and absorption and adsorption of gases and vapors on building surfaces.

3. meteorological factors--These include indoor-outdoor temperature relationships, wind pressures and the amount of moisture (humidity) in the air.

4. permeability of the structure--This is a measure of how much air can infiltrate the building.

5. ventilation measures--There is an inverse relationship between the concentration of an indoor pollutant and the magnitude of ventilation within a building.

A study performed by Nagda, Koontz, and Rector (1985) showed that indoor concentrations of pollutants rises at a slower rate than the outdoor levels of pollutants. Furthermore, the indoor concentration peaks somewhat later than for the outdoor concentration. The reverse is also true. This indicates that the building envelope has a dampening or shielding effect on the indoor peak concentration which is only a temporary condition if the outdoor pollutants are allowed to continue to infiltrate into the building.

Indoor Sources of Pollutants

The presence of indoor sources increases indoor concentrations. The variations of emissions of pollutants, due either to operational changes or changes in environmental conditions, must be considered in evaluating the impact of one or more sources on indoor air quality (Esmen, 1978). Table 2.2 lists sources of major contaminants which may be found on the exterior and interior of buildings.

Rate of Air Exchange

The rate of air exchange is the rate at which indoor air is exchanged with outdoor air. The rate is defined as the volume of air exchanged per unit of time (Turiel, 1985, pp. 8-9). The volume of air is usually expressed in terms of the volume of the structure, and one hour is used as the time unit. For example, a building which has a volume of 50,000 cubic feet, where 12,500 cubic feet of outdoor air enters the structure per hour to replace the same amount of indoor air, the air exchange rate is 12,500/50,000 or 0.25 air exchanges per hour (ACH). The air exchange rate is a factor in determining the amount of time required for the concentration of the indoor contaminant to decrease.

Air is exchanged between the outdoor and indoor environment by such processes as infiltration, natural ventilation and mechanical ventilation. Infiltration of air into or out of a building is caused by a pressure difference between the two spaces. The pressure difference can be caused either by temperature changes, wind, or both. For instance, in the colder months, the outdoor to indoor temperature difference causes warm indoor air to rise and leave through openings in the upper part of the structure and colder outdoor air to enter through openings in the lower part. The reverse can happen during the warmer months of the year. When wind impacts a building, it creates a pressure difference between the inside and outside surface which, in turn, allows air to enter or leave a structure at a faster rate (Nagda, Koontz, and Rector, 1985).

Ventilation refers to the amount of air flowing into or out of a building. There are two types of ventilation; natural and mechanical. Natural ventilation is the air flowing into or out of a structure through window, door, and other openings. It is also caused by changes in temperature and/or wind pressure. Mechanical (sometimes called forced) ventilation is produced by a motorized fan or other mechanical equipment. Mechanical ventilation can occur in the entire building such as that produced by a central air handling or ventilation system or localized such as a special unit servicing one room or a part of a room (i.e., room air conditioner or exhaust fan over a stove) ("Indoor Air Quality Environment," 1987, pp. 3-53, 3-62).

Volume of Structure

The concentration of any indoor pollutant is dependent on the volume that is available in which the contaminant can disperse. For example, the concentration of a pollutant in a building having a volume of 30,000 cubic feet would be approximately twice as high as for one having a volume of 60,000 cubic feet for the same source of emission. This assumes that the entire indoor volume is equally available for the pollutant to disperse. If a source were located only in one room and the door to that room remained closed, the entire indoor volume would not be equally available. The same would hold true if the source were located on the second floor of a building since the contaminant would remain mainly on that floor and infiltrate outdoors at or above this level (Meyer, 1983, chap. 4).

Characteristics of Pollutants

Physical and chemical characteristics of a pollutant are important in determining indoor concentrations. Research performed by Esmen (1978) showed that nitrogen dioxide concentration decreases much more rapidly than that of carbon monoxide mainly due to different methods of chemical reactions that each undergoes when exposed to the elements in the air.

Nagda, Rector, and Koontz (1987) presented data that showed the impact of air exchange on formaldehyde is less than that expected for other pollutants such as carbon monoxide. "This limited reduction occurs because as the air exchange rate increases, the rate at which formaldehyde emanates also increases" (p. 22). On the other hand, Hernandez and Ring (1982) found for radon that when one increases the ventilation rate, the concentration of the pollutant is reduced.

Pollutant Removal

There are many ways to remove pollutants from the indoor environment. The major methods are to increase ventilation rate, use air cleaning devices, remove source(s) from the environment and encapsulate the source(s) (Turiel, 1985, chap. 8).

Both natural and mechanical ventilation can reduce the concentration of most indoor-generated pollutants as can air infiltration. In the case of mechanical ventilation the location of the exhaust can play an important role in determining indoor air quality. Nagda, Rector, and Koontz (1987) stated, "An exhaust fan located directly adjacent to an indoor source will have greater impact than one that ventilates the entire building" (p. 22). Localized mechanical ventilation is often used to remove a specific pollutant such as smoke. Furthermore, the use of localized or spot forced ventilation is more economical than attempting to ventilate the entire structure at the same rate. The same basics hold true for natural ventilation such as opening a window to rid a room of a specific contaminant such as smoke. This, of course, will take more time than using mechanical ventilation. In addition, it will probably upset the temperature and humidity conditions within the indoor space.

The major disadvantage to increasing the rate of ventilation is the resulting increased cost of energy. The use of air-to-air heat exchangers can help minimize the energy consumption. This is mechanical equipment which can be used to conserve the otherwise lost energy by utilizing the warm air that is being vented to warm outdoor replacement air in the winter and the cool air that is being vented to cool outdoor replacement air in the summer. These pieces of equipment are most efficient in locations where the differences between indoor and outdoor temperatures are greatest ("Indoor Air Quality Handbook," 1982, pp. 94-100).

Pollutants can also be removed through the use of air cleaning devices. Various types of these are commercially available ranging from small room units to larger ones that are designed to handle an entire building. The removal of pollutants is accomplished by the use of filters. There are various types of filter mediums available. The special type used will depend on the type of pollutant that is to be filtered, its size and concentration (Turiel, 1985, pp. 96-106).

Another method of pollutant removal relates to the source itself. Either the source is removed, or it is encapsulated. The latter is the process of covering or coating the source with an impervious medium which will not allow the pollutant to enter the indoor environment. The material and method used will depend on the contaminant being contained ("Indoor Air Quality Handbook," 1982, chap. 5).

Finally, in specific cases, a property of the pollutant itself can assist in reducing its indoor concentration according to studies performed by Hernandez and Ring (1982). In their work with radon and radon progeny, they found that the concentration can be reduced through an increased rate of the progeny plating or settling out on surfaces instead of remaining in the air when central air handling units existed in the building and rates of air exchange were not increased.

Combination of All Effects

When examining the factors which effect indoor pollution one must consider all of them in combination. A convenient method of doing this is through the use of a mathematical equation known as the mass balance relationship (Nagda, Rector, and Koontz, 1987, p. 24). The equation written in narrative form is presented below:

Accumulation Rate of a Pollutant = Rate of Input from Infiltration of Outdoor Air Containing Pollutant + Generation of the Pollutant Indoors - Infiltration of Indoor Air Containing Pollutant - Indoor Removal of Pollutant

Health Effects of Indoor Air Pollutants

In order to more effectively and efficiently monitor and alleviate problems with indoor air pollution, one must first understand the effects contaminants can have on one's health. According to Turiel (1985), "Two factors that must be assessed in order to predict health effects are exposure levels and typical human responses for various levels of exposure" (p. 5). Table 2.3 contains a list of common pollutants and the concentration that has been found to create health-related effects on building occupants.

Table 2.3

Threshold Concentrations of Major Indoor Air Contaminants

Pollutant	Level	Standards and guidelines
Radon and Radon daughters	4 pCi/1	EPA guideline for indoor concenration
	5 pCi/1	EPA action level for residential weatherization program
	5.4 pCi/1	ASHRAE recommended exposure level in residences
Formaldehyde and other organic compounds	0.05 to 0.4 ppm	Proposed indoor air standards for formaldelyde compounds compounds in some states
Nitrogen oxides	0.056 ppm	EPA average one year outdoor air quality limit for nitrogen dioxide
	0.25 ppm	California one-hour standard for nitrogen dioxide
Carbon oxides	9 ppm	EPA average eight hour outdoor air quality limit for carbon monoxide
	35 ppm	EPA average one hour outdoor air quality limit for carbon monoxide
Inhalable particles	5000 μg/m^3	OSHA eight-hour average limit for respirable inert or nuisance dust
	260 μg/m^3	EPA twenty-four hour ambient air quality standard for total suspended particles
Allergins and pathogens		none

Note. From Indoor Air Quality Environmental Information Handbook: Building System Characteristics (Contract No. DE-AC01-81EV10450) (pp. 1-2). United States Dept. of Energy, 1987, Washington, D.C.

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When discussing the health effect(s) any one pollutant has on any one individual, one must consider the severity of the effect. One system of classifying various degrees of severity was developed by Gammage (1986). It contains five separate categories each of which are defined below:

1. Chronic--Long lasting illness which can result in death. An example is cancer induced by asbestos or radon exposure.

2. Acute--Illness which exists only when exposed to the pollutant, such as watering of the eyes when exposed to formaldehyde. If acute illness is allowed to continue it can turn into chronic illness.

3. Hypersensitivity--Highly individualized reaction to one or more pollutants such as from passive cigarette smoke.

4. Impaired sense of well-being--A reaction caused by a low tolerance for specific levels of environmental conditions. An example would be a feeling of stuffiness caused by an inadequate amount of fresh air.

5. Imaginary--Illness only exists in one's mind, not physically.

Many times it is hard to differentiate among the various classifications listed above.

In terms of a real illness, the effect which any pollutant has on an individual is expressed in the form of a dose-response relationship (Turiel, 1985, pp. 10-12). As noted above, responses may include acute symptoms such as headaches to more serious chronic complications such as cancer. The dose refers to the amount of pollutant inhaled or exposed to a specific part of the body. According to Turiel, the dose is dependent upon the concentration of the contaminant, the rate at which the individual takes in air, and the body's clearance rate for each specific pollutant.

Wesolowski (1984, p. 313) noted that the concentration of the pollutant depends on the following:

1. Volume of air contained in the indoor space.
2. Rate of production or release of the pollutant in the indoor space.
3. Rate of elimination of the contaminant in the indoor space through filtration, reaction, or settling.
4. Ratio of the air exchanged with the outside environment through infiltration, natural or forced ventilation.
5. Concentration of the pollutant outdoors.

Other factors that must be considered, according to Wesolowski, are the concentrations at any one point within the building, vapor pressure and other meteorological parameters.

Relative to Turiel's (1985, pp. 10-12) other two factors, individuals vary in their respiratory rates and in their responses to various pollutants. According to Environmental Science & Technology ("Indoor Air Pollution," 1980), "Determining when, where and how exposure occurs is the key not only to limiting exposure, but even [sic] to understanding the fundamental effects of pollution correctly" (p. 1023).

When studying the health effects any one or combination of pollutants has on an individual or group of people, both toxicological and epidemiological data must be obtained and examined. In essence this information is obtained by studying health effects in two different ways by two different branches of the health profession: toxicologists and epidemiologists. Both methods are statistical in nature and deal with probabilities.

In studying health effects, the toxicologist examines the absorption, detoxification and excretion rates for each pollutant or combination of pollutants at various body sites. Instead of determining each of these factors, the responses to known exposures are usually studied by administering the substance(s) in known amounts to animals or human volunteers (Turiel, 1985, p. 10). Questions that are considered by researchers in this area of study are: Is there a threshold or minimum dose required before the effect is manifested? Is the substance toxic only when large doses are given within a short time span (days or weeks)? Is the substance toxic when small doses are given over a long time period (year or more)?

When studying short-term response, one would look for changes in respiratory rate, keenness of perception, psychological effects or diseases of various kinds. Some of the long-term effects include cancer, birth defects and altering of genetic material according to Turiel (1985, pp. 10-13).

Epidemiological studies begin with the effect and work back to probable causes by analyzing the health histories and habits of groups of people living or working in the same environment. Most epidemiological studies deal with tests of association and a single study can almost never be interpreted as proving causation. For example, an epidemiological study might show that there is a very strong association between the existence of radon and lung cancer (which is the apparent cause), but it cannot prove scientifically that radon caused the cancer. The advantage of these types of studies is that the illness can be studied in the environment where it naturally occurs (Meyer, 1983, chap. 8).

A problem faced by epidemiologists is determining an average exposure to a pollutant to be assigned to all members of a population, given that the concentration of various pollutants varies with time and location. According to Turiel (1985):

> In order to obtain a person's total exposure to a chemical, it would be necessary to have a time history of their [sic] daily movements and knowledge of the concentration in air of that chemical at all locations, preferably at the breathing zone (p. 12).

To attain this, a personal air monitor would have to be worn during the entire study, which would be cumbersome if not impossible.

In studying the health effects of pollutants, epidemiologists attempt to eliminate the effects of as many of the factors involved as possible. Two population groups are selected that are similar in terms of such factors as median age, sex ratio, social structure, racial composition, and others, but different in terms of exposure to the same pollutant.

No matter what form of study is performed, the researcher must always keep in mind that many of the initial human responses to the existence of one or more contaminants are exactly the same as those which occur when temperature and humidity conditions are unsatisfactory within the facility. Int-Hout (1984) stated:

> A typical response to condition of slight warm discomfort is a sensation described as "stuffiness." The limited studies available show that other symptoms may occur over prolonged exposure to a slight warm discomfort, such as increased odor sensitivity, headaches and irritability. These begin to sound like many of the tight building syndrome complaints. (p. 100).

Investigations performed by the National Institute of Occupational Safety and Health (cited in Melius, et al., 1984) suggested that when temperatures are in the mid 70s range and the relative humidity is between 30% and 70%

reported cases of building-associated illnesses are minimal to nonexistent. Furthermore, Morey (1984) showed in his studies that when the relative humidity is above 70% there is an increased posibility that deleterious microorganisms such as mold will develop within the structure and affect the occupant's health.

There are many health effects associated with the wide range of indoor pollutants. Table 2.4 is a summary of the major pollutants and the known health effects of each. Much study still remains to be performed in the effects of indoor pollutants. Presently, for example, information does not exist on the long-term effects of low levels (some of which cannot be measured) of one or a combination of several pollutants. In addition, Kevan and Howes (1980) stated,

> What is needed is an increased awareness of the serious relationship which exists between both long- and short-term exposure to pollution on not only pathological, but also psychological conditions of the people living in such environments. (p. 289).

Formaldehyde

Many studies have been performed on the effects of formaldehyde as a pollutant (Ritchie and Lehnen, 1985, Pickrell, Mokler, Griffis, Hobbs and Bathlja, 1983, Konopinski, 1983, Olsen and Dossing, 1982, and Van Der Wal, 1982). All of these studies are consistent in their findings. At low temperatures (such as those found in most

Table 2.4

Health Effects of Major Indoor Air Contaminants

Descriptive summary	Health effects
Respirable Suspended Particles (RSP)	
Particles or fibers in the air small enough to be inhaled. RSP is a broad class of chemically and physically diverse substances. Tobacco smoke is usually the largest indoor source. Other sources include fireplaces, wood stoves, unvented gas appliances, kerosene heaters, asbestos construction material, house dust.	Health effects depend on particle size and chemical composition. Primary effects of concern are nose, throat, eye irritation, respiratory infection, bronchitis, emphysema, heart disease. Asbestos fibers and tobacco smoke particles linked to lung cancer. Radon progeny attach to particles and can lodge in the lung.
Combustion gases	
Carbon monoxide (CO) and nitrogen dioxide (NO_2) are gases formed during the use of gas stoves, unvented gas & kerosene space heaters, and woodstoves. Tobacco smoke is another source. CO increases when there is an inadequate supply of combustion air; NO_2 increases with higher combustion temperature.	CO interferes with the delivery of oxygen throughout the body. Mild oxygen deficiencies can affect vision and brain function. NO_2 can irritate skin, eyes, and mucous membranes. NO_2 produces respiratory illnesses ranging from slight burning and pain in the throat and chest to violent coughing and shortness of breath. Chronic effects of long-term low-level exposure are uncertain.
Allergens and pathogens	
A wide variety of bacteria, viruses, fungi, pollen, algae, etc., which can produce infection, disease or allergic reaction. Major sources are human activity and domestic animals. Excessive humidity, standing water, reduced ventilation, and use of untreated recirculating air can increase concentrations of microorganisms.	Common viral diseases (chicken pox, measles, influenza), respiratory infections, asthma, allergic reactions of the skin, nose, airways, and lungs.

(table continues)

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Table 2.4

Health Effects of Major Indoor Air Contaminants

Descriptive summary	Health effects
Radon	
A naturally occurring radioactive gas which enters primarily from underlying soil & rock. Other sources include drinking water and building materials.	Radon itself decays and produces radioactive decay products. If inhaled, these decay products can lodge in the lungs and irradiate surrounding tissue. Scientists estimate 5,000-20,000 ung cancer deaths per yr. in the U.S. may be due to radon.
Formaldehyde	
A strong smelling water soluble gas used as a component of some insulation and of adhesives used in making plywood, particle board, and fiberboard. Other sources include furniture drapes, carpet, paper products.	Principal effects are eye, nose, throat irritation. Individual sensitivities vary. Long-term exposure causes nasal cancer in animals.
Organic compounds	
A wide variety of chemicals used in household products (cleaners, paints aerosols, deodorizers), pesticides, building materials, and furnishings Also released by smoking, and gas or wood burning appliances.	Difficult to assess, due to variety of compounds, interactions, etc. Some are irritants, some are carcinogenic. Some affect the central nervous system, or interfere with metabolic processes.

NOTE. From *Indoor Air Quality Environmental Information Handbook: Building Characteristics* (Contract No. DE-AC0181EV10450) (pp. 2-2 & 2-3) United States Department of Energy, 1987, Washington, D.C.

buildings) formaldehyde vaporizes to a colorless gas having a strong odor. Most people can smell levels of one part formaldehyde per million parts of air (ppm). At levels of from two to three ppm, mild irritation of the eyes and nose results. At higher levels the effects include difficulty in breathing, nausea, emphysema and cancer. One can also obtain skin irritations from the substance according to Life & Health ("Formaldehyde-A Hazard," 1981). If exposed to formaldehyde over a long period of time, one will develop an allergic reaction to it.

Radon

Studies on the effects of radon indicate that the one concern is cancer (Bruno, 1983, Hileman, 1983, Hinds, Rudnick, Maher and First, 1983). The decomposition of radon into its radioactive daughters or progeny causes decay of a person's longs. This process, if allowed to continue, will eventually lead to lung cancer.

Monitoring Indoor Air Quality

When speaking about monitoring indoor air quality, the word measurement is used in a broad sense. It includes measurements performed through the use of chemical and physical methods for sampling and analyzing contaminant concentrations, air exchange rates and other environmental factors such as temperature and relative humidity. Furthermore, questionnaires and other types of surveys can be used in indoor pollution studies to obtain related information such as characteristics of the building, type and condition of building support systems and occupant activities.

The measurement of specific pollutants begins with an understanding of the most current monitoring techniques, threshold standards for specific contaminants and methods used in determining health effects of indoor pollution. Since there are so many factors which affect the concentration of any one pollutant and its effect on any one individual, not to mention the hundreds of contaminants which have been identified to date, the measuring activity is quite complex. Currently, reliable measuring techniques do not exist for all levels of any one or combination of several pollutants ("Indoor Air Quality Environmental," 1987). The results of recently completed studies indicate the measuring for the existence, concentration and effect of indoor pollutants is a multi-fold activity (Turiel, Hollowell, Miksch, Rudy, Young, and Coye, 1983, Mintz, Hosein, Batten and Silverman, 1982, Taylor, Dell'Acqua, Baptiste, Hwang and Sovik, 1984). A complete and comprehensive measuring procedure must consider verbal responses from those in the environment as to how they feel physically and psychologically; results of physical (and possibly psychological) examinations of the building's occupants; and direct measuring or monitoring of the air quality to ascertain if any contaminants exist and, if so, in what concentrations. In addition, a building survey should be performed to determine the types of materials and systems from which the building is constructed and their condition. The survey should also include the types of activities occurring in the facility and the composition of materials being used in them.

Most measuring activities begin as a result of complaints by the building's occupants. Light (1987) suggested that complaints may be related to the presence of known contaminants such as gas fumes or result from the occurrence of health-related symptoms suspected to be caused by indoor pollutants (known or unknown). Since there are so many factors which can affect the quality of the indoor air, a complete study of the indoor environment is a very expensive undertaking. Therefore, prior to dedicating a large amount of resources to the investigation, preliminary studies should be undertaken. Wallingford (1986) and Salisbury (1986) found that it is best not to devote a large amount of resources to undertake a sophisticated air monitoring and evaluation program. They both indicated the first step should be the documentation of the health complaints, determination of the prevalence of symptoms among building occupants, and the compilation other related information.

The initial investigation should begin by visiting the facility and speaking with the people involved. The site visit team may include professionals from many disciplines including physicians, ventilation consultants, building contractors, pest control operators and trained indoor environmental investigators such as those from NIOSH (Light, 1987). Once the appropriate investigation team has been assembled, the next step is to determine how the investigation will be made and the design of survey forms such as questionnaires to help identify causal factors. According to Godish (1986), the survey form(s) should enable the investigators to collect information on "(1) patterns of symptom onset, (2) building history, including renovation and maintenance practices, (3) potential contaminant sources, and (4) air handling systems, their operation and maintenance" (p. 193).

The development of survey instruments should be given deliberate consideration. They should not be hastily prepared. As with any survey instrument the appropriate steps should be followed in its preparation. If using an instrument prepared by someone else for a different project, be sure it is closely reviewed to ascertain if it applies to the present situation; and if not, make the appropriate changes. It is beyond the scope of this dissertation to present an in-depth discussion on the preparation of such instruments. The reader is referred to work done by Koontz and Nagda (1985) for specific details on this task.

Once the investigation procedure has been developed the next step is making the actual visit. It should begin with an opening conference attended by the investigator(s), building manager(s), office manager(s), maintenance personnel and employee representative(s). The purpose of this conference is to discuss the nature of the complaints and symptoms along with determining if any previous actions have been taken to improve the indoor air quality in the building.

Following the opening conferences, a walk-around inspection of the building is performed utilizing survey or inspection forms to record one's observations. Information that should be obtained include the materials from which the building is constructed and their condition; the types of support systems contained in the facility and their condition, the types of activities occurring in the building and the materials and equipment utilized in their performance (Salisbury, 1986). An adequate amount of time should be scheduled to perform the needed inspections. The purpose of this activity is to locate any known sources of indoor contaminants.

During the inspection, special attention should be paid to the heating, ventilating and air conditioning (HVAC) system. Through January 1, 1986, NIOSH has completed over 350 investigations of health complaints from occupants of governmental and other office buildings, schools and colleges and health care facilities (cited in Salisbury, 1986). In over 50% of the investigations, inadequate ventilation was found to be the cause (other causes were existence of sources of indoor contaminants, 20%; outdoor pollutants infiltrating indoors, 10%; smoking, 2%; high humidity, 5%; noise/illumination, 1%; infectious airborne organisms, 3%; and unknown, 9%). These figures reinforce the need to carefully examine the air handling system and its condition.

When inspecting the HVAC system, the following should be considered (Hughes and O'Brien, 1986):

1. Type and configuration of the system which can be determined from the construction drawings and/or contractor who installed it. This information can also be obtained from a thorough inspection performed by a ventilating specialist.

2. Location of outside air intake and exhaust vents. These should not be in close proximity of each other.

3. Presence of standing water and/or microbial contaminants (i.e., sludge) in the system.

4. Location of interiorair supply and return vents and thermostats.

5. System operation in terms of start-up and shutdown times along with thermostat settings.

6. Level of maintenance performed on the system including filter changes, lubrication, treatment of any water used, and yearly balancing.

The next task is to acquire information about the people who are occupying the facility. This includes both those who are making the complaints or experiencing the health-related symptoms and those who are not. A very systematic approach utilizing standard questionnaires is required. The survey should acquire standard epidemiological information such as age, sex, job duties and materials used, smoking history, health history, and symptoms experienced. The absentee rates for the current and previous year(s) should also be obtained. The objective of acquiring this information is to determine the scope of the problem within the facility and to attempt to isolate it to specific area(s) and cause(s) (Salisbury, 1986).

An additional component of a total survey program is genetic testing. As noted in Environmental Science & Technology ("Indoor Air Pollution," 1980), there are two techniques used: screening and monitoring. Genetic screening is done once to determine if a person has specific genetic traits which would make him or her a higher risk of being affected by one or more pollutants. Genetic monitoring involves periodically examining building occupants by collecting blood or other body liquids to assess whether damage has occurred in certain cells. Genetic monitoring and/or testing cannot be used alone to evaluate the effects of indoor pollutants. Other factors, besides genetic composition, can cause a person to be predisposed to illness from the environment. These include age, gender, pre-existing illness, nutritional status, personal habits and prior exposure to certain environmental factors.

During this stage of the investigation, one must look for any "hidden causes" of complaints. These include improper building construction or operations, a labor-management problem and/or complaints about uncomfortable temperatures or relative humidities (Carlton-Foss, 1983). The building occupants' attitudes and beliefs must be carefully assessed to determine which have validity and which do not. This is accomplished through careful observations and discussions with the occupants including the use of well formulated questionnaires.

High or low temperatures and/or relative humidities can result in a feeling of discomfort within the building. This, in turn, can lead to health-related complaints about the environment similar to those expressed when problems exist with indoor air pollution. Therefore, in any analysis of the indoor environment temperatures and relative humidities need to be measured and altered, if needed, to provide a comfortable, healthy space. ASHRAE's Standard 55-1981 entitled Thermal Environmental Conditions for Human Occupancy (1981) should be referred to when evaluating existing temperature and/or relative humidity conditions. This standard provides guidelines for acceptable temperatures and relative humidities which depend on such factors as type of occupant activity, type of clothes worn by the occupant, and season of the year. For a typical school building the temperatures range from 67°F to 80°F and relative humidities from 30% to 70%. Because of the complexity of the relationship among all the variables, a ventilation specialist should be consulted when planning to make temperature and/or relative humidity changes.

Once these investigative studies have been completed the results are analyzed. The purpose of the analysis is to attempt to determine whether a positive association exists between the pattern of illness and such items as: (a) recent building renovations; (b) building maintenance practices; (c) the use of a specific type of equipment or substance; and (d) heating versus cooling modes of the ventilation equipment (Godish, 1986). Here again, various specialists should be involved in all or a part of the analysis as needed including personnel from local departments of health.

The results of the analysis will either be the identification of one or more causes of the reported illness or an inadequate amount of information to come to any conclusions at this point in the investigation. In the latter case, additional measurements will be needed in an attempt to determine the cause(s). These measurements can be split into two groups. The first will be those that measure the effectiveness of the air handling system. The other measurement is that of the air quality itself or more specifically the monitoring of the air for specific contaminants and their concentrations.

Since 50% of the indoor air quality problems investigated by NIOSH relate to the ventilation system as the cause, resources should be dedicated to first testing the efficiency of the system. The previous examination and analysis of the system discussed above did not include measuring air exchange. ASHRAE has developed and published Standard 62-1981 entitled, Ventilation for Acceptable Indoor Air Quality (ASHRAE, 1981). It establishes minimum air exchange rates (cubic feet of air per minute [CFM] per occupant) for rooms based on type of building such as office, the type of activity occurring in the room such as cooking, and whether or not smoking is allowed. These standards have been adopted by architects, engineers and constructors in this country. The recommendations for school buildings can be found in Table 2.5. Because low ventilation rates have been determined to cause increased concentrations of certain pollutants, the standard is now being reviewed for possible revision. If changed, the new minimum air exchange rates will be 15 cfm per person for classrooms, music rooms, libraries and auditoriums, and 20 cfm per person for laboratories and training shops. Smoking would not be allowed in these rooms. If space is set aside for smoking, the minimum air exchange rate would be 60 cfm per person.

The measurement of air exchange can be a very time consuming and costly process. The two commonly used procedures are pressurization and tracer-gas techniques. The first method entails increasing the air pressure in the building through the use of fans and measuring the leakage to the outdoors. The tracer-gas method introduces a gas into the building environment and measurements are made at predetermined locations to ascertain the amount of air exchange which exists. Both of these methods are relatively complex and require specialized equipment and a considerable amount of follow-up mathematical analysis (Nagda, Rector and Koontz, 1987, pp. 43-52).

Table 2.5

ASHRAE 1981-61 Ventilation Standards for School Buildings

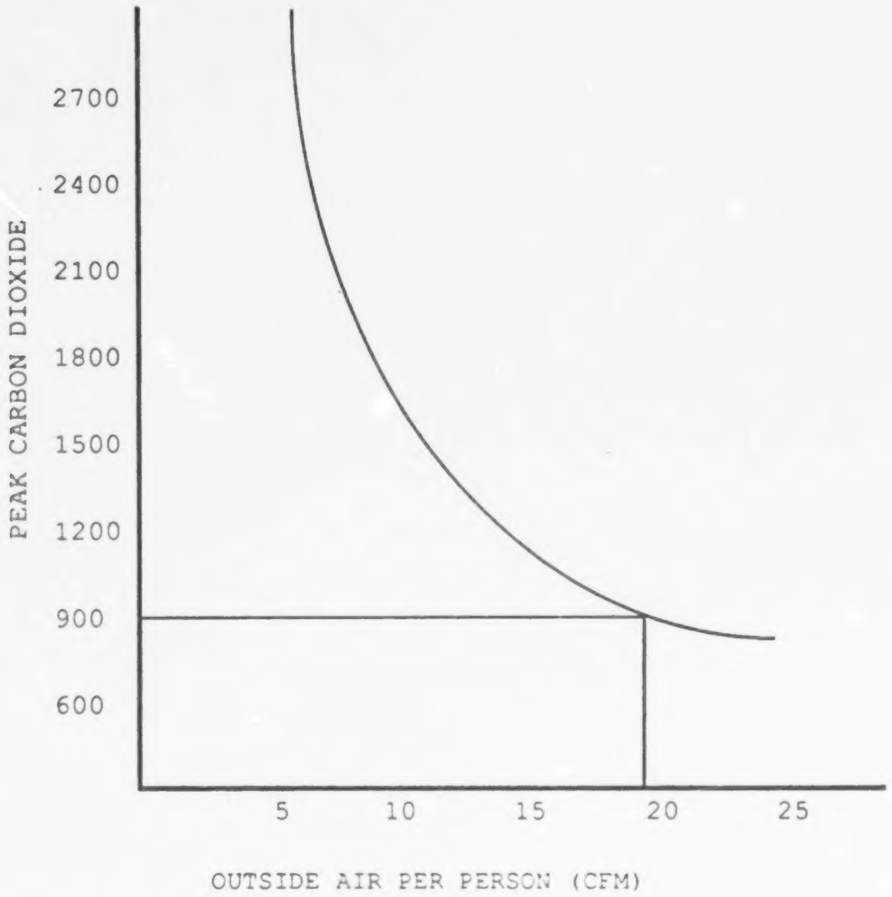
Room type	Outdoor air requirements-CFM/ppm	
	Smoking	Non-Smoking
Classrooms	25	5
Labs	--	10
Training Shops	35	7
Music Room	35	7
Libraries	--	5

NOTE. From Ventilation for Acceptable Indoor Air Quality (p. 9) American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Standard 62-1981.

An alternative technique has been developed by ASHRAE and is contained in their Standard 62-1981, Appendix D (ASHRAE, 1981). Gammage (1986), Godish (1986), Wallingford (1986), and Salisbury (1986) indicated they have used this method in their research of ventilation efficiency and found it to be not only acceptable, but also less costly. The method is based on the relationship of concentrations of carbon dioxide measured in parts per million and the amount of air exchange measured in cubic feet per minute. Through a series of equations, a graph can be developed illustrating the relationship between the two variables. Figure 2.1 shows the graph and the equations on which it is based.

The researcher, using special chemically treated glass tubes and a vacuum pump, will take samples of the air by breaking the ends of the tubes off and pulling air through them. The amount of carbon dioxide in the air is noted by examining the tube and reading the concentration (ppm) directly from the chemically treated scale. For example, if the concentration of carbon dioxide is 1000 ppm, the scale will be discolored to the 1000 mark. The higher the concentration, the less efficient the ventilation system. This method is accurate to plus or minus 10%. The more samples which are taken, the more accurate the results. Time and money will determine the number of samples which can be taken. The reader is referred to Table 2.6 for the corresponding concentrations of carbon dioxide for the

Figure 2.1. Ventilation efficiency based on indoor carbon dioxide levels.



ASHRAE Rationale for Minimum Physiological Requirements for Respiration Air Based on CO_2 Concentration

Indoor CO_2 = Outdoor CO_2 + N/V; N = CO_2 Generation Rate = 0.63 ft^3/hr/person; V = Ventilation Rate as ft^3/hr/person; % CO_2 Indoors = .0325% + ((0.63 x 100) / (CFM x 60)), = .0325% + (1.05 / CFM); CFM per person = 1.05 / (% CO_2 Indoors - .0325%)

Note: From Ventilation for Acceptable Indoor Air Quality (p. 9) American Society of Heating, Refrigeration, and Air-Conditioning Engineers, Standard 62-1981.

Table 2.6

Concentrations of Carbon Dioxide Comparisons to ASHRAE 1981-61 Ventilation Standards for School Buildings

Room type	Carbon dioxide concentrations/ppm	
	Smoking	Non-Smoking
Classrooms	745	2425
Labs	---	1375
Training Shops	625	1825
Music Room	625	1825
Libraries	---	2425

existing ASHRAE minimum air exchange rate shown in Table 2.5. For the proposed standards the following are the concentrations: 1050 ppm for 15 cfm per person; 850 ppm for 20 cfm per person; and 500 ppm for 60 cfm per person.

If the results of the ventilation tests indicate problems, the appropriate corrections should be made. This will require the employment of ventilating specialists. If the alleviation of the air exchange problem did not correct the indoor air quality problem or if the problem is not with the air handling equipment, the investigator will need to monitor the air for one or more contaminants and locate the source(s).

Once it has been determined that air quality measurements are needed, a plan or design should be established for monitoring the pollutants. The first part of the plan is to develop monitoring objectives. They indicate what pollutants are to be monitored, what is the relative importance of each contaminant if more than one, what are other factors to be measured, and what are some design alternatives that might be considered (Nagda, Rector and Koontz, 1987, chap. 5).

Indoor measurement of air contamination, according to Wadden and Scheff (1982, chap. 2) requires consideration of a variety of factors. These include the selection of air sampling equipment and an analytical technique with an adequate sensitivity, selection of a meaningful time scale for the measurements, the calibration of sampling and analytical methods, and consideration of the effects of human activities on the level of the pollutant(s) being measured.

The second part of the plan, therefore, is to identify available instrumentation and where and when the measurements will be taken. The latter information will be project specific and includes seasons of the year, time and day of the week and spaces (buildings and/or rooms) and geographic areas to be monitored. The identification of measuring instrumentation is in itself a time-consuming task and only the basics of it will be presented here.

Wesolowski (1984) stated:

> Although there are a variety of instruments that have been developed for industrial and outside air pollution monitoring, these instruments often cannot be easily used in the outdoor environment for a number of reasons, including their size, cost, interferences and the noise they make (p. 314).

Recent studies resulted in the development of a number of devices especially for use in the indoor environment (Wesolowski, 1984, Godish, 1984, Molhave, Bisgaard and Dueholm, 1983).

When reviewing the various types of instruments available, one must consider certain factors. These are mobility, operating characteristics, output characteristics, and whether the instrument is available as a unit or must be assembled from a number of commercially available units (Nagda, Rector, and Koontz, 1987, pp. 76-80). Relative to mobility, there are three classifications: personal, portable and stationary. The personal device is one that is worn by individuals in the environment being monitored. The other two cannot be worn due to their size and weight. As noted, one can be easily moved from location to location (portable) and the other because of its size cannot (stationary).

Within each mobility class one can further classify the instrumentation by its operating characteristics. Some devices are active in that they require a power source to draw air into a sensor or collector. The balance are classified as passive since no power is required. In this case, the sample is collected by diffusion; that is, the pollutants, contained in the air, settle out on a medium that has been designed to indicate, with or without further testing, whether or not the contaminants exist.

In terms of output characteristics, there are two classes. The first is a collector-type device. This instrument only collects an air sample that must be sent to a laboratory for analysis. The other class is referred to as an analyzer device. This unit produces instantaneous results by analyzing the air sample as it is drawn in it and providing the user with the information on the concentration level of the pollutant.

Which device to use will depend on the specific project, the pollutants to be monitored, the concentrations to be monitored and available resources such as time, personnel and money. One must also consider ongoing activities in the facility to be monitored and whether or not they can be interrupted. It should be noted that instruments presently do not exist to monitor all concentrations of all known pollutants. Furthermore, it is not possible to measure very low concentrations of combinations of specific pollutants which may be causing health-related problems (Godish, 1986). It is beyond the scope of this presentation to present detailed information about the various specific types of monitoring instrumentation and their operation. The list of references contains additional information on this subject.

Once the monitoring design objectives have been finalized and the appropriate instrumentation has been selected, the next step is to monitor the air. This should be done in accordance with the protocol established for the project. The various aspects to be included are sample size, sampling time, sampling location, setting up and operating monitoring devices, obtaining and recording data from devices, procuring and sending air samples to the laboratory for analysis and results thereof, maintaining and calibrating instrumentation, performing quality control and assurance activities, and the development of appropriate use of forms or other documentation (Nagda, Rector, and Koontz, 1987, chap. 5).

The final step is to compare the results of the monitoring with threshold or acceptable limits for the specific pollutant. Presently standards exist for outdoor pollutants only. As noted earlier in this chapter, they have been developed by the Environmental Protection Agency. These standards are used as the basis for all pollution measurement and evaluation work outdoors. They are also used as a beginning point (especially if no other data are available) when analyzing the existence of pollutants within buildings. Acceptable air-quality standards for non-industrial type building interiors have not been established. Many organizations, both public and private, are working to develop such standards (Spengler and Sexton, 1983). Many of these appear in Table 2.3.

Formaldehyde

Presently, an acceptable threshold level for formaldehyde in most individuals is 0.1 ppm. Turiel (1985, p. 17) indicated that a concentration of between 0.1 and 0.5 ppm is acceptable for indoor exposures. However, in the upper part of the range, hypersensitive individuals may experience health-related problems.

Instruments currently being used to monitor formaldehyde include permeable membranes, diffusion tubes and colorimetric devices ("Monitoring Report," 1983, Godish, 1984, Sexton, Liu, and Petrea, 1986, Monsen and Stock, 1986). Most of these are portable or personal active devices. The diffusion tube is a passive monitor and easily adapts to use in school buildings.

Radon

As for formaldehyde, an acceptable national standard for radon does not exist. The National Research Council (cited in Windham, 1986) suggests a standard of 3 pico-Curies/Liter of air (pCi/L).

There are both passive and active measuring devices available commercially (Windham, 1986, and George, 1986). According to this research, passive portable monitors are the type in greatest use today and are also adaptable for use in school buildings. These type of monitors include the activated charcoal canisters and alpha track detectors. The Environmental Protection Agency (1986) has developed a protocol for monitoring radon. If relatively high rates are found as a result of the initial measurements, recommendations are provided to the investigator for further monitoring.

Alleviating and Preventing Indoor Air Pollution

Based on the presentation above, there are two basic methods of improving indoor air quality: source emission reduction and air concentration reduction. According to Wesolowski (1984), the first method requires one to initially identify the source, using the methods described herein. Once identified, the effects of the source can be minimized or eliminated by:

1. Removal of source or substitution.
2. Design change.

3. Encapsulation such as covering the surface with an impermeable surface-coating.

4. Confining the source to an area with limited air exchange with the rest of the building.

5. Minimizing source use to reduce contamination when people are exposed.

All of these methods will require the use of specialists trained and experienced in the specific technique. See Table 2.7 for methods of source alteration.

To reduce the concentration of pollutants, either increase the rate of air exchange or reduce the concentration of the contaminant(s). In the latter case, the Indoor Air Quality Handbook (1982) recommends using mechanical filtration, absorbing surfaces and electrostatic precipitators. The adoption and implementation of these methods will require specialists to design and install the equipment. Less popular techniques are establishing no smoking areas, eliminating space dividers that tend to restrict the movement of air or reducing the occupancy of the building. See Table 2.8 for methods of contaminant removal.

The actual method selected should be based on a complete analysis of the specific situation. The variables that should be considered are pollutant(s) to be eliminated, source, adaptability of method to source and pollutant, direct and indirect cost of performing the mitigation technique, accessibility of source; ongoing activities

Table 2.7

Methods of Source Alteration to Reduce Indoor Air Contamination

Method	Description	Potential applicability
	Source modification	
Removal of substitution	Source of contaminant is removed from dwelling; it is replaced by a less contaminating source that fulfills the same basic function if one is required and available.	All sources
Change in design	Source of contaminant is altered in its design so that it will have a lower emission	All sources
Encapsulation	Source is covered by a material that is impermeable to the contaminant and restricts introduction of contaminant into the indoor air	Continuous nonmechanical mechanical sources
	Source usage	
Spatial confinement	Source is used in a confined area that has limited air exchange with remainder of the dwelling	Localized sources
Temporal use	Source is used only when few people will be exposed to the contaminant and/or when the contaminant concentration can be reduced by removal	Inhabitant-controlled sources

NOTE. From Indoor Air Quality Handbook (Sand 82-1773) (p. 86) United States Department of Energy, 1982, Washington, D.C.

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Table 2.8

Methods of Contaminant Removal to Reduce Indoor Air Contamination

Method	Description	Potential applicability
	Air exchange	
Infiltration and exfiltration	General exchange of indoor and outdoor air through cracks moves a portion of indoor contaminants to outside; it may also move outdoor contaminants indoors	All contaminants
Natural ventilation	General exchange of indoor and outdoor air by intentionally opened windows, doors, and vents moves a portion of indoor contaminants to outside; it may also move outdoor contaminants indoors	All contaminants
Mechanical ventilation	General exchange of indoor and outdoor air by forced-air moveent moves a portion of indoor contaminants to outside; it may also move outdoor contaminants indoors	All contaminants
Local ventilation	Movement of indoor contaminants from a specific source mechanical ventilation	Contaminants localized
	Air cleaning	
Mechanical filtration	Particles are trapped as air passes through a filter	Particles
Adsorption	Gaseous contaminants are adsorbed on materials with large surface areas such as activated charcoal, alumina, and silica gel	Some organic gases and vapors
Electrostatic interaction	Particles become changed as they interact with ions or pass through an electric field and are removed from the air by becoming attached to oppositely charged surface	Particles

NOTE. From Indoor Air Quality Handbook (Sand 82-1773) (p. 88) United States Department of Energy, 1982, Washington, D.C.

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adjacent to source; and resources required and their availability. If the specific situation is life-threatening, measures will usually be taken, no matter what the cost, to correct the situation, including moving the building occupants to another location. The process becomes more complicated when the situation is causing acute or lesser health symptoms. There are no clear and concise avenues to alleviate the problem in this case. A trial-and-error method could be applied. Many times, effort and other resources may be needed to correct the otherwise unhealthy situation.

Prevention of the occurrence of indoor air pollutants is a matter of developing a comprehensive building-use program and making those affected aware of it. Such a program should include:

1. Establishing an inventory of all materials and systems of which the building is comprised. The inventory can be placed in a manual format or on computer. It would include information about each building component such as material type, manufacturer, maintenance recommendations and dates when inspection and preventive maintenance activities should be and are performed. The inventory would serve as a resource for investigators to use in the event that indoor air pollutants are suspected to be causing health problems of the occupants (Liska, 1980, chap. 3).

2. Designing and implementing an effective and efficient preventive maintenance program for the facility. Based on manufacturer's recommendations and those of others

in the building and maintenance profession, establish inspection intervals and times for performing routine maintenance items such as changing air filters. Assign the necessary resources such as money and personnel to the program. Also establish a follow-up program to insure the required inspection and maintenance items are being performed correctly (Liska, 1980, chap. 2 & 3).

3. Updating existing air distribution systems, if inadequate, to provide the needed air exchange to prevent problems from indoor pollution. It may also be necessary to increase the frequency of maintenance on existing systems and building materials (Morey, 1984).

4. Staying abreast of current research findings on the subject of indoor air pollution. Make needed changes to the existing building maintenance program and building operations consistent with any pertinent findings (Morey, 1984).

5. Monitoring the day-to-day activities in and outside of the building to ensure that known sources and/or causes of indoor air pollutants are not introduced into the environment.

When planning and designing a new facility or remodeling or renovating an existing one, provide ample opportunity for those involved to review the drawings and technical specifications relative to potential problems with indoor air quality and the utilization of materials which are known sources of indoor pollutants. Dedicating the needed resources of time, personnel and money and the results of the most up-to-date research findings, will help insure that buildings are designed so that all possible sources of indoor pollution are "built-out" of the facility. Furthermore, an effective and efficient heating, ventilating and air conditioning system should be selected for the specific building taking into consideration the potential of indoor pollution (Hughes and O'Brien, 1986, Frazier, 1984, and McNall, 1986).

It is the responsibility of the design profession to develop formal methods such as checklists to insure that future buildings are not only constructed efficiently from a standpoint of both first costs and costs incurred to operate the facility, but that the occupants of the building are provided an environment that will not be deleterious to their health. On the other hand, it is the responsibility of the appropriate school personnel to select design professionals who are capable and experienced in performing such activities. To help insure a healthy environment, it would be ideal to install a continuous pollutant monitoring system to the building. Such a system would constantly monitor the quality of the air and provide a warning when specific pollutant concentrations rise above a predetermined level.

Presently, a system as described, is not available to monitor all the typical indoor pollutants. However, similar systems are used in industrial environments for certain contaminants, thus the technology exists to design indoor air monitoring systems for schools and other related type buildings. Smith (1983) provided a comprehensive study of how a monitoring system should be designed, installed, and maintained, and what one can do with the information it provides. Table 2.9 is a summary of control techniques for some of the major pollutants.

Formaldehyde

Research studies sponsored by the United States Department of Energy ("Indoor Air Quality Environmental," 1987, pp. 2-31) indicate two things can be done, either individually or together, to alleviate the effects of formaldehyde. These are:

1. Increase the air exchange rate per hour within the building.

2. Seal the sources which have the capability of outgassing formaldehyde.

The prevention of problems from formaldehyde can be realized by not installing any materials in the building which are known sources or by utilizing materials having a low formaldehyde rating along with providing an adequate amount of air exchange. Refer to Table 2.10 for methods of control for formaldehyde.

Radon

The results of research on radon ("Indoor Air Quality Environmental," 1987, pp. 2-19) indicate that the following methods are most effective in alleviating problems with the pollutant:

Table 2.9

Control Techniques for Indoor Air Contaminants

Descriptive summary	Control techniques
Respirable Suspended Particles (RSP)	
Particles or fibers in the air small enough to be inhaled. RSP is a a broad class of chemically and physically diverse substances Tobacco smoke is usually the largest indoor source. Other sources include fireplaces, wood stoves, unvented gas appliances, kerosene heaters, asbestos construction material, house dust.	- Avoid smoking tobacco indoors - Be sure woodstove doors and flues do not leak - Vent combustion appliances outdoors - Supply outdoor air directly to woodstove and fireplace firebox - Effectiveness of air cleaning devices varies widely. Electrostatic precipitators and high efficiency (HEPA) filters are most effective. - Change air filters regularly
Combustion gases	
Carbon monoxide (CO) and nitrogen dioxide (NO_2) are gases formed during the use of gas stoves, unvented gas & kerosene space heaters and wood stoves. Tobacco smoke is another source. CO increases when there is inadequate supply of combustion air; NO2 increases with higher combustion temperature	- Pay attention to operating & maintenance instructions on space heaters. Improper wick length or air shutter tuning can effect CO & NO_2 emissions. - Choose a properly sized wood stove or space heater to heat your home. - Maintain adequate ventilation. Use local ventilation i.e., vented range hoods on gas stoves, when possible.
Allergens and pathogens	
A wide variety of bacteria, viruses, fungi, pollen, algae, etc., which can produce infection, disease or allergic reaction. Major sources are human activity and domestic animals. Excessive humidity, standing	- Maintain low relative humidity levels - Eliminate any stagnant water associated with humidifiers, air conditioning equipment, saunas, etc.

(table continues)

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Table 2.9

Control Techniques for Indoor Air Contaminants

Descriptive summary	Control techniques
water, reduced ventilation use of untreated recirculating air can increase concentrations of microorganisms.	- Air cleaning devices may and remove microorganisms and allergens. Filters should be cleaned frequently.
Radon	
A naturally occurring radioactive gas which enters homes primarily from underlying soil & rock. Other sources include drinking water and building materials.	- Seal off pathways between the soil or crawl space and outdoors - Ventilate soil to draw radon gas away from home - Ventilate crawl space - Overpressurize basement to inhibit radon entry - Increase air exchange in tight rooms - Air cleaning under study
Formaldehyde	
A strong smelling water-soluble gas used as a component of some insulation and of adhesives used in making plywood, particle board and fiberboard. Other sources include furniture, drapes, carpet, paper products.	- Use "low fuming" formaldehyde products - Seal or treat surfaces to reduce emissions - Maintain low indoor humidity levels - House, ventilation, air cleaning, ammonia fumigation under study.
Organic compounds	
A wide variety of chemicals used in household products (cleaners, paints, aerosols, deodorizers), pesticides, building materials, and furnishings. Also released by smoking, and gas or wood burning appliances.	- Pay attention to warning & instructions for storage and use - Use only in well ventilated areas - Substitute less hazardous products, e.g., use of a liquid or dry form of a product vs. an aerosol spray.

(table continues)

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NOTE. From Indoor Air Quality Environmental Information Handbook (Contract No. DE-AC01-81EV10450) (pp. 2.2-2.3) United States Department of Energy, 1987, Washington, D.C.

Table 2.10

Control Techniques for Formaldehyde

Control method	Specific control	Comments
Change in design	Naturally aged particle board and other urea formaldehyde containing products or induce aging by heat treatment to cause outgassing before use	Effectiveness unknown
Substitution	Use thermal insulation other than urea-formaldehyde foam	
Substitution	Replace particle board with solid wood	
Encapsulation	Cover particle board with shellac, varnish, polymeric coating, or other diffusion barriers	Effectiveness unknown

NOTE: From Indoor Air Quality Handbook (Sand 82-1773) (p. 101) United States Department of Energy, 1982, Washington, D.C.

1. Increase the rate of fresh air exchange. This is the most effective way.

2. Clean the air using electronic precipitators. This method is not as effective but can be used with one or more of the other ways.

3. Seal off the source(s) of radon. This can be difficult or even impossible to accomplish, depending on how the building was designed and constructed. Data published by the National Institute of Building Sciences (1985) explain how to effectively seal the structure.

To prevent, or at least minimize, problems from radon in new construction, the first thing is to determine if the site being considered on which to construct the building is a potential source of the pollutant. An experienced soil consultant or geologist should be utilized in this process. If the site does contain sources of radon and must be used for the building or an investigation is not performed, design and construction methods outlined by the National Institute of Building Sciences (1985) should be followed. Another alternative would be to consider another site. Table 2.11 lists methods of controlling radon.

Conclusion

This chapter presented the results of a literature search on the topic of indoor air pollution and the effects it can have on building occupants. Table 2.12 summarizes the cited references in this dissertation and the objectives to

Table 2.11

Control Techniques for Radon and Radon Progeny

Control method	Specific control
Removal	Do not build in areas of uranium or phosphate mining or where tailings have been used for landfill
Removal	Excavate high radium-containing soil and fill with low radium-containing soil
Substitution	Use building materials with low radium content, not high radium content
Encapsulation	Seal cracks in basement walls and concrete slabs with polymeric caulks to prevent introduction of radon from soil
Encapsulation	Cover basement walls and concrete slabs with epoxy paint, polymeric sealant, or polyethylene or polyamide film (vapor barrier) to prevent introduction of radon from soil or concrete
Encapsulation	Improve slab construction to reduce cracks through which radon can penetrate
Local ventilation	Ventilate crawl space
Physical filtration	HEPA filtration
Electrostatic interaction	Electrostatic precipitation

NOTE: From Indoor Air Quality Handbook (Sand 82-1773) (p. 112) United States Department of Energy, 1982, Washington, D.C.

Table 2.12

Summary of Objectives and Related Cited References

Objectives	Cited resources
1. Present a case analysis for the ten schools.	All references related to this objective
2. Develop, field test and finalize survey forms which will be used as part of the final document for this study.	Godish, 1986 Hughes & O'Brien, 1986 Koontz & Nagda, 1985 Liska, 1980 Melius, et al., 1984 Meyer, 1983 Nagda, et al., 1987 National Institute of Building Sciences, 1985 National Research Council, 1981 Salisbury, 1986 Turiel, 1985 Wadden & Scheff, 1982 Wallingford, 1986 Wesolowski, 1984
3. Take physical measurements of temperature, humidity, carbon dioxide and the contaminants radon and formaldehyde using the appropriate instrumentation and monitoring devices.	Anderson, et al., 1974 Drivas, et al., 1972 Echolm, 1986 "Formaldehyde-A Hazard," 1981 Gammage, 1986 George, 1986 Godish, 1984, 1985a, 1985b, 1986 Godish, 1984, 1985a, 1985b, Hager, 1985 Hernandez & Ring, 1982 Hileman, 1983 Hinds, et al., 1983 Hughes & O'Brien, 1986 "Indoor Air Quality Environmental," 1987 Konopinski, 1983 Lowder, et al., 1971 McGregor & Courgun, 1980 Melius, et al., 1984 Meyer, 1983 Mintz, et al., 1982 Molhave, et al., 1983 Monson & Stock, 1986 Morey, 1984 Nagda, et al., 1985, 1987 National Research Council, 1981 National Institute of Building Science, 1985

(table continues)

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Table 2.12

Summary of Objectives and Related Cited References

Objectives	Cited resources
	Olsen & Dossing, 1982 Pickrell, et al., 1983 Prichard, 1978 Ritchie & Lehner, 1985 Rundo, et al., 1979 Salisbury, 1986 Schery, 1986 Sexton, et al., 1986 Smay, 1985 Taylor, et al., 1984 Turiel, 1985 Turiel, et al., 1983 Van Der Wal, 1982 Wadden & Scheff, 1982 Wallingford, 1986 Windham, 1986
4. Determine the level of awareness of indoor air pollution	All references relate to this objective
5. Develop a process to diagnose and alleviate health-related problems from indoor air pollution.	Bruno, 1983 Carlton-Foss, 1983 Caruba, 1984 Gammage, 1986 Godish, 1985a, 1986 "Indoor Air Quality Environmental," 1987 Melius, et al., 1984 Meyer, 1983 Morey, 1984 National Institute of Building Science, 1985 National Research Council, 1981 Salisbury, 1986 Sexton & Wesolowski, 1985 Tennessee Valley Authority, 1984 Turiel, 1985 Turiel, et al., 1983 Wadden & Scheff, 1982 Wallingford, 1986 Wesolowski, 1984 Yocum, 1982 Yocum, et al., 1971

(table continues)

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Table 2.12

Summary of Objectives and Related Cited References

Objectives	Cited resources
6. Identify information which can be used in the development of guidelines to prevent indoor air pollution.	American Lung Association, 1984a, 1984b Bruno, 1983 Caruba, 1984 "Cleaning the Air," 1986 Esmen, 1978 Frazier, 1984 Gammage, 1986 Godish, 1985a, 1986 Hager, 1985 "Indoor Air," 1980 "Indoor Air Quality Handbook," 1982 "Indoor Air Quality Environmental," 1987 Light, 1986 Liska, 1980 McNall, 1986 Melius, et al., 1984 Meyer, 1983 Nagda, et al., 1985, 1987 National Institute of Building Science, 1985 National Research Council, 1981 Salisbury, 1986 Sexton & Wesolowski, 1985 Smith, 1983 Tennessee Valley Authority, 1984 Turiel, 1985 Turiel, et al., 1983 Wallingford, 1986 Yocum, 1982 Yocum, et al., 1971
7. Increase readers' awareness of indoor air pollution.	All references relate to this objective.
8. Suggest areas for further research.	Carlton-Foss, 1983 Caruba, 1984 Frazier, 1984 "Indoor Air Quality Handbook," 1982 "Indoor Air Quality Environmental," 1987 Int-Hout, 1984 Kevan & Howes, 1980 Kirsch, 1982, 1986 Melius, et al., 1984 Meyer, 1983

(table continues)

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Table 2.12

Summary of Objectives and Related Cited References

Objectives	Cited resources
	Morey, 1984 Nagda, et al., 1987 National Institute of Building Sciences, 1985 National Research Council, 1981 Salisbury, 1986 Spengler & Sexton, 1983 Turiel, 1985 Wadden & Scheff, 1982 Wallingford, 1986 Wesolowski, 1984

which they pertain. The diagnosis, alleviation, and prevention of indoor air contaminants in school buildings must become a concern of every school administrator providing the students, teachers, and staff with a healthy indoor environment will help maximize the effectiveness of the teaching/learning process.

The information contained in this chapter has shown that indoor air pollution is an important health-related problem. It is anticipated that it will become even more important in the future as more energy-efficient buildings are constructed, as the use of synthetic materials in consumer products and building materials become more prevalent, and as the public's awareness of this problem increases. The local school building administrator will have to deal with the problems on a daily basis. He or she will be able to deal with them more effectively as research efforts, such as this, establish a clearer understanding of the nature and magnitude of the problem, develop more effective evaluation methods and design and implement reasonable, cost effective mitigation and prevention procedures.

Chapter Three

Methodology

The methodology used to conduct this study consisted of performing a series of activities or tasks. Many of these were exploratory in nature and others involved the use of aspects of descriptive designs. The performance of each activity was related to the accomplishment of one or more of the study objectives listed in Chapter One. At the end of this chapter there is a table summarizing the various objectives and related activities.

Task Number One: Development of Survey Forms

The first part of the study entailed the development of a series of survey instruments. These instruments were used to obtain certain types of information from which follow-up action was taken as described in this chapter. The first form developed was the Health Information Form (HIF). This document is in Appendix A. The purpose of this document was three-fold. First, it was used as the basis for selecting school buildings which served as field test sites for this study. Second, the information from the HIF was used in analyzing the results of the field test site investigations and resulting findings. Finally, in its revised format, it became part of the final document of this study.

The items contained in the HIF were developed using information obtained from the literature search performed for this study, presentations made at conferences on indoor air quality, and communications with recognized experts in the field. It, therefore, is a document which reflects the latest technology on the sources and health-related effects of indoor contaminants. Other than the general information items, each one pertains to one specific source or health-related symptom of indoor air pollution.

The format of the instrument was designed to be clear and concise. It requires a relatively short amount of time to complete. Most of the items are closed form in that the respondent circles one of the choices which he or she perceives as the appropriate one. Most items have three choices from which to select.

The document is divided into four parts. Part I provides general information required to conduct the study along with five questions related to known outdoor causal factors of indoor contaminants. The responses to Part II will help in ascertaining whether there are any types of equipment, materials and/or processes in the building which may be sources of indoor pollutants. This part also contains a few questions relating to the maintenance of the building. There are a total of fifteen questions in Part II. Parts III and IV relate to sensory perceptions (symptoms) and health-related symptoms, respectively. The responses to these questions will help determine if known reactions to indoor contaminants are perceived to exist in the school buildings. There are six questions in Part III and twenty-eight in Part

IV. Part IV also contains a question on when absenteeism was above average for the 1985-86 school year and the perceived reason(s) for it. The last item asks if the respondent would consent to participate in any follow-up research. There is also space provided at the end of the form for comments the respondent may have about it.

The second survey instrument, entitled Comprehensive Building Survey Form (Appendix B), and third survey document, entitled Room Survey Form (Appendix C), were developed for this study for two purposes: first to be used in the inspection of the field test schools; and second, in their revised format, to be included as part of the product of this dissertation.

Both of these forms were developed by this author based on previous research on the subject of building maintenance and repair as contained in Building and Plant Maintenance Desk Book (Liska, 1980). Each form contains instructions on how to go about performing an inspection. Space is available to record one's observations and to document the results of any measurements made of the interior building environment such as temperature, humidity and test results of monitoring air for specific pollutants.

Each form contains the following:

1. Instruction on how to perform the inspection and complete the form.

2. A series of items, one or more of which relate to a specific piece of construction (i.e., windows) or to a

building support system (i.e., window air conditioning unit) and their condition.

3. Space to record general types of information which may help locate sources of indoor contaminants.

There is a mixture of open and closed type items. The design of the format makes the items self-explanatory to the user. However, unlike the HIF, these take a longer amount of time to complete. The inspection forms were validated as a result of extensive use by the researcher prior to conducting this study.

Task Number Two: Acquiring Initial Data

After the HIF had been developed, the next step was to select a sample of schools in South Carolina to which the form would be sent. It was initially decided to send the HIF to the 816 K-8 public schools listed in the Directory of South Carolina Schools: 1985-86 (1985). After analyzing the financial resources available to perform this part of the research, it was decided to send the form to a random sample of 650 of the 816 schools.

A cover letter was developed which explained the purpose of the study (Appendix D). An original letter, a HIF and a self-addressed, stamped envelope, was sent to the principal of each school in the sample. A deadline was given in the letter for the return of the completed form. To maximize the rate of return, phone calls were made to about half of those principals who had not returned their forms by the prescribed date. Due to existing financial constraints, those called were located in the upstate of South Carolina. A total of 329 completed forms (51%) were returned.

Task Number Three: Analysis of Data From Health Information Form

The next step was to analyze the data contained on the completed Health Information Forms. There were two purposes for this activity. The first was to select the ten schools which would serve as field test sites. The second was to provide quantitative data which was used as part of the overall analysis of the information obtained from the school inspections.

The procedure used to select the ten schools began as the completed forms were received. Each one was scored relative to the potential of problems with indoor air contaminants. The scoring entailed reviewing the response to each question and assigning a point if the response indicated a potential for indoor air pollution. For instance, it is known that gas stoves are a source of indoor air contaminants. If the respondent indicated the existence of one or more gas stoves in his building by answering yes to question number three in Part II of the HIF, one point was assigned to it. Table 3.1 presents a summary of the scoring procedure. The final score which each form received was the sum of the scores of the individual items.

The next step in the selection process was to develop a frequency distribution of all the total scores from the forms

Table 3.1

Summary of Procedure for Scoring Health Information Form

Questionnaire part	Question numbers	The following response receives one point for each question
I	1-4	Yes
	5	Well
II	1-10	Yes
	11	Heating: Gas, Coal or Oil-Fired Cooling: Gas, Room A/C
	12	No
	13	Poor or Non-Existent
	14	No
	15	Yes
III	1-3	1, 2, 4, or 5
	4	4 or 5
	5 & 6	1 or 2
IV	1-28	Yes

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received. The ten schools were selected from this distribution. The first five schools were those that scored highest in the HIF, did not contain asbestos, and consented to take part in the follow-up study. The remaining five were those that scored lowest on the form, did not contain asbestos, consented to take part in the follow-up study, and were located in at least one of the same counties as any of the first five schools. School buildings containing asbestos were not included in this study because of the high level of awareness which exists among school personnel about the pollutant and its effects.

The principal of each school selected was contacted by phone to obtain commitment to be involved in the on-site study and to receive written permission for same. At the time of the original phone contacts, appointments were made to visit each school. Follow-up letters (Appendix E) were sent to each principal confirming this information. In one case, permission was not received, and the next school on the list was selected.

The second part of the analysis consisted of deriving a series of frequency distributions for both the total sample and for the two groups of five schools. The SAS computer software program was utilized in this effort. The first series presented how the respective sample responded to each item on the HIF. The second series consisted of the total scores to the four parts of the form. Finally, the last series shows various comparisons among categories of sources (scores from Part I and II of the form) and categories of symptoms (scores from Part III and IV of the form). This part of the analysis was primarily exploratory with the goal of obtaining information which would be used in developing the process for the final product of this dissertation. In addition, the results of the analysis would help in determining the principal's level of awareness of indoor air pollution.

Task Number Four: Inspecting School Buildings

The next part of this study was to perform an on-site inspection of the ten school buildings. The purpose of each visit was to:

1. Substantiate the responses to the items on the HIF.

2. Determine, for the five schools selected which scored highest on the HIF, whether the reported health-related symptoms were caused by the existence of known sources of indoor contaminants or some other reason such as communicable diseases.

3. Inspect each building and record the types of materials and systems of which it is comprised; along with the condition of each.

4. Observe and record the types of activities and the materials which were being used in and around each building.

5. Obtain and record temperature and relative humidity data at randomly selected locations within each building.

6. Place passive monitoring devices for radon in each building in accordance with the recommendation of the manufacturer.

7. Place passive monitoring devices for formaldehyde in a number of the buildings. Those buildings receiving the devices were those where sources of formaldehyde were observed.

8. Take air samples to determine the level of carbon dioxide which is a measure of the adequacy of the building's ventilation system.

9. Field test the entire inspection procedure including the organization and completeness of the survey documents, placement and retrieval of the monitoring devices and adequacy of the time and the level of expertise needed to carry out the task.

10. Determine the level of awareness of the building principal of indoor air pollution.

The on-site visits were scheduled so that two schools could be inspected each day. Since it was important to obtain levels of carbon dioxide while the building was occupied, the schools were visited while classes were in session. However, classes were not interrupted. A typical visit was performed as noted herein.

The first activity was an opening conference with the principal. The purpose for the visit was reviewed along with how it would specifically take place. The information contained on the HIF which was completed by the principal was

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reviewed, and any missing data obtained; in the cases of those schools where the potential for problems with indoor pollution was high, discussion took place as to whether or not the principal perceived there existed such a problem. Any other information obtained from the interview that was pertinent to this study was recorded on separate sheets of paper. This discussion also gave this author a chance to evaluate the level of awareness of the principal to the problem of indoor air quality based on how he or she responded to many of the questions.

Since passive test monitors had to be left at each school for a number of days, the principal was asked if he or she would allow them to be placed in areas inaccessible to students and at a designated time, retrieve them and place them in pre-addressed, stamped containers and mail them to the testing laboratory. Finally any special needs, such as getting into a locked boiler room, were addressed at this time.

Upon the completion of the opening conference, the actual inspection took place. The inspection included both the building exterior and interior. Since so many of the classrooms were similar, only a few of them were inspected in each building. The Comprehensive Building Survey and Room Survey Forms were used during the inspection process. Following the instructions contained on the form, inspections were performed and information requested was provided.

Temperature and relative humidity measurements were taken in all the classrooms, teacher lounges, and some of the other rooms inspected. The instrument used for these measurements was an electronic digital hygrometer. In addition, air samples were taken for the purpose of obtaining the levels of carbon dioxide using a Sensidyne Gastec Pump and extra low-range carbon dioxide indicator tubes. The results of these measurements were recorded in the appropriate places on the two inspection forms.

Another task conducted during the inspection was the placement of passive monitoring devices for radon and formaldehyde. At least three radon monitoring devices were placed in rooms inaccessible to the students. The monitoring instrument used for this study was a commercially available charcoal packet. The devices were placed in accordance with the manufacturer's recommendations. All ten schools were monitored for radon.

Relative to monitoring for formaldehyde, the devices were placed only in buildings in the sample of ten that contained rooms or spaces where there existed observed sources of the compound. A passive monitor (named PF-1) manufactured by Air Quality Research of Berkeley, California, was used in this research.

Along with each inspection, pictures were taken for future reference. After the inspection was complete, a closing conference was held with the principal. During this time he or she was informed of any unusual items observed which might potentially cause health-related problems. In addition the principal was informed where each of the monitoring devices was left. In addition, the procedure of retrieving, packing and shipping was discussed with each one. Finally each principal was informed that a copy of the study would be made available to him or her and if the results from the passive test monitors indicated any problems, they would be contacted as soon as possible.

The exposed radon monitors were sent to A. E. Labs of Dallas, Texas, for analysis. This laboratory is approved by the Environmental Protection Agency to perform radon analysis. The formaldehyde devices were sent to the manufacturer for analysis. Once the test results were received, they were reviewed to ascertain whether any problems existed. The results also recorded on the appropriate survey form.

Task Number Five: Development of Case Analyses

Utilizing the data from the three survey forms an analysis was developed for each test site. The analysis included the following items:

1. Summary of information about the various materials, equipment, and system of which each facility was comprised.
2. Observed sources of contaminants inside and outside the building which could affect the quality of the indoor air.
3. Range and mean of the temperature and relative humidity measurements taken within the building.

4. Range and mean of the carbon dioxide levels and if any one of the measurements exceeded the recommended maximum.

5. Range and mean of the radon test results and the formaldehyde test results. In addition, if any one of the test results exceeded the recommended threshold level, this was so noted.

6. The apparent cause of any symptoms reported on the HIF.

7. Findings as to the perceived level of awareness of the principal (and others interviewed) of indoor air pollution.

8. Information relating to any problems encountered during the actual inspection process including the use of the survey forms.

9. Other information which might have had a bearing on the development of the final document for this dissertation.

Once the case analysis for all the schools was completed, general conclusions were derived. In addition, recommendations were derived which were incorporated in the development of the final document.

Task Number Six: Designing the Process for the Final Document

The process was developed as a step-by-step procedure. It utilized essentially the same steps taken to conduct the methodology of this dissertation. However, it incorporated the recommendations which were derived from the field-test site case analyses. Finally, this task included the revision of the three survey forms which are part of the final process.

Where applicable, resources were identified for each step in the process. In addition, where personnel and/or services were required that are most likely not available in the school or school district, references were identified for use by the school principal.

Task Number Seven: Development of Document on Indoor Air Pollution

The last major effort in this dissertation was the development of a document which the school building administrator can use to diagnose, alleviate, and prevent indoor air pollution. This document can also be used to increase the level of awareness of school personnel to potential problems with poor indoor air quality.

The development consisted of taking the steps derived in the previous task and placing them, along with any supplementary data, into a format that can be understood and easily used by the school building administrator. To support each step, instructions were included throughout the document as needed.

In its present form, it can be used not only for its original purpose, but also for awareness training. Finally, it can be used as a guide when reviewing construction drawings and specifications for known sources of indoor contaminants for the purpose of preventing any health-related problems.

Task Number Eight: Identifying Areas for Further Research

This task was performed throughout the entire study. As situations were encountered where additional research was needed, such as how often carbon dioxide measurement should be taken, it was so noted in this investigator's records.

Summary

This chapter presented the methodology that was used to perform this study. The methodology consisted of a series of tasks, each of which contributed to the attainment of one or more of the objectives of this dissertation. Table 3.2 has a summary of the objectives and related tasks.

Table 3.2

Summary of Objectives and Tasks to Attain Them

Objectives	Task number(s)
1. Present a case analysis for the ten schools.	4, 5
2. Develop, field test and finalize survey forms which will be used as part of the formal document for the study.	1, 2, 3, 4
3. Take physical measurements of temperature, humidity, carbon dioxide and the contaminants radon and formaldehyde using the appropriate instruments and measuring devices.	4
4. Determine the level of awareness of indoor air pollution among principals.	3, 4
5. Develop a process to diagnose the alternate health-related problems from indoor air pollution.	4, 5, 6
6. Identify information which can be used in the development of guidelines to prevent indoor air pollution.	7
7. Increase readers' awareness of indoor air pollution.	7
8. Suggest areas for further research.	1-7

Chapter Four

Findings

This chapter presents the findings of the research performed for this dissertation. The findings will be presented for each of the objectives of this study. Since many of the objectives are related and overlap in their intent, one may find some duplication in the presentation of the findings.

Objective 1: Present a Case Analysis for Each of the Ten Schools Visited from which Qualitative-Based Conclusions will be Developed which will Serve as Data to be Included in the Development of the Final Document of this Study

As specifically described in Chapter Three, ten schools were selected from among those which returned the completed HIF. Five of these had a high potential and the other five a low potential of problems with indoor air pollution.

Six hundred fifty forms were sent out with 329 completed ones being returned, for a 51% rate of return. Upon their receipt, the forms were scored as described in Chapter Three. Table 4.1 shows a frequency distribution of the scores both in terms of the number obtaining a specific score and the percentage of the total return. Using Table 4.1, ten schools were selected for follow-up study. The reason why the five schools scoring the highest and the five scoring lowest were

Table 4.1

Frequency Distribution of Scores on Health Information Form

Score	Frequency in numbers and (percentages)
1	11 (3)
2	40 (12)
3	53 (16)
4	51 (16)
5	46 (14)
6	34 (10)
7	18 (5)
8	11 (3)
9	10 (3)
10	9 (3)
11	5 (2)
12	4 (1)
13	7 (2)
14	4 (1)
15	5 (2)
16	2 (1)
17	2 (1)
18	4 (1)
19	2 (1)
20	1 (<1)
21	2 (1)
22	2 (1)
23	1 (<1)
24	1 (<1)
25	1 (<1)
26	1 (<1)
27	0 (0)
28	0 (0)
29	0 (0)
30	0 (0)
31	1 (<1)
32	1 (<1)
Total	329 (100)

not selected from Table 4.1 was because they did not meet all the established criteria presented in Chapter Three.

To further analyze the data from all the completed Health Information Forms returned, additional statistics were derived. Table 4.2 presents a summary of how each of the items on the HIF were responded to in terms of the frequency of the number of respondents selecting each choice and the percent of the total responding. Table 4.3 is a summation of the numbers shown in Table 4.2 for each part of the form. It provides the reader with the total number of outdoor sources of pollutants, indoor sources of pollutants, sensory-related symptoms, and health-related symptoms. This information was developed for use in making comparisons between categories of sources of indoor air pollution with categories of health and sensory symptoms as shown in Table 4.4.

Because the information on the HIF could not be verified for all the schools surveyed, it was decided not to perform any further analysis in the data. Due to the great number of variables and possible combination of relationships, this investigator did not attempt to come up with any significant findings for the entire sample.

Based on the responses shown in the last part of Table 4.4 (total sources compared with total symptoms), it appears for the schools surveyed, that a greater percentage of those do not have either sources (84%) or symptoms (85%) known to be caused by the sources. This, however, is not the case for

Table 4.2

Summary of Responses From All Schools on the Health Information Form

Part I. General Information: Potential External Sources of Indoor Pollutants

Item	Choice No. of responses (percent of total)			Not responding
	Yes	No	Don't know	
1. Does the building contain asbestos?	47(14)	257(78)	23(7)	2(1)
2. Are there any "smoke stack" industries within one mile of the building?	24(7)	293(89)	8(3)	4(1)
3. Is there a creek or other open body of water adjacent to the building which is accessible to the building's occupants?	25(8)	299(91)	4(1)	1(<1)
	Yes	No	Don't know	
4. Is there a land fill or garbage dump within one mile of the building?	24(7)	289(88)	9(3)	7(2)

(table continues)

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Table 4.2

Summary of Responses From All Schools on the Health Information Form

Item	Choice				Not responding
	No. of responses (percent of total)				
	Well	City	County	Other	
5. What is the source of your drinking water in the building?	42(13)	237(72)	46(14)	1(<1)	3(4)
Part II. Equipment Materials and Processes in the Building: Potential Internal Sources of Indoor Pollutants					
	Yes	No	Don't know		
1. Space Heaters-Kerosene:	2(1)	322(98)	0(0)		5(1)
	Yes	No	Don't know		
2. Space Heaters-Natural Gas:	78(24)	242(74)	1(<1)		8(2)
3. Gas Stoves:	78(24)	242(74)	1(<1)		8(2)
4. Humidifiers:	4(1)	312(95)	5(2)		8(2)

(table continues)

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Table 4.2

Summary of Responses From All Schools on the Health Information Form

Item	Choice			Not responding
	No. of responses (percent of total)			
	No. of responses (percent of total)			
5. De-humidifiers:	4(1)	311(95)	4(1)	10(3)
6. Electronic Air Cleaners:	12(4)	303(92)	6(2)	8(2)
7. Do you have chemistry laboratories in the building?	20(6)	306(93)	1(<1)	2(1)
	Yes	No	Don't know	
8. Do you have home economics laboratories in the building?	57(17)	266(81)	2(1)	4(1)
	No. of responses (percent of total)			
9. Do you have an industrial arts shop in your building?	35(11)	291(88)	1(<1)	2(1)
10. Is smoking allowed in the building?	248(75)	76(23)	0(0)	5(2)

(table continues)

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Table 4.2

Summary of Responses From All Schools on the Health Information Form

		Item	Choice				Not responding
			No. of responses (percent of total)				
			Yes	No	Don't know		
11.	Heating:	Gas-Fired	95(29)	234(71)	N/A		N/A
		Oil-Fired	129(39)	200(61)	N/A		N/A
		Coal-Fired	7(2)	322(98)	N/A		N/A
		Electric-Powered	129(39)	200(61)	N/A		N/A

(table continues)

		Item	Yes	No	Don't know		Not responding
	Cooling:	Gas	9(3)	320(97)	N/A		N/A
		Electrical	98(30)	231(70)	N/A		N/A
		Central Air Conditioning	111(34)	218(66)	N/A		N/A
		Room Air Conditioners	169(51)	160(49)	N/A		N/A
		None	32(10)	297(90)	N/A		N/A
12.	Does a formal maintenance program exist for the building, on paper?		203(62)	113(34)	N/A		13(4)
			Excellent	Average	Poor	Non-Existent	
13.	What is your perception about the level of maintenance in your building?		(100(30)	206(63)	19(6)	0(0)	4(1)

(table continues)

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Table 4.2

Summary of Responses From All Schools on the Health Information Form

Item	Choice					Not responding
	No. of responses (percent of total)					
	Yes	No	Don't know			
14. As far as you know, are air filters changed regularly in your heating, ventilating and air conditioning units?	297(90)	18(5)	12(4)			2(1)
15. Is there mold or mildew anywhere inside the building?	49(15)	240(73)	37(11)			3(1)
	Cold		Acceptable		Hot	
	5	4	3	2	1	
1. Building Temperature	5(2)	11(3)	278(84)	15(5)	17(5)	3(1)
	Humid		Acceptable		Dry	
	5	4	3	2	1	
2. Humidity	8(2)	15(5)	287(87)	9(3)	8(2)	2(1)

(table continues)

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Table 4.2

Summary of Responses From All Schools on the Health Information Form

Item	Choice					Not responding
	No. of responses (percent of total)					
	Drafty		Acceptable		Stuffy	
	5	4	3	2	1	
3. General Comfort	4(1)	13(4)	285(87)	13(4)	10(3)	4(1)
	Stale		Acceptable		Fresh	
	5	4	3	2	1	
4. Air Quality	8(2)	13(4)	279(84)	19(6)	5(2)	5(2)
	None		Acceptable		Strong	
	5	4	3	2	1	
5. Odor	33(10)	22(7)	235(71)	23(7)	9(3)	7(2)

(table continues)

Table 4.2

Summary of Responses From All Schools on the Health Information Form

Item	Choice					Not responding
	No. of responses (percent of total)					
	Acceptable				Unacceptable	
	5	4	3	2	1	
6. Overall Rating of Environment	56(17)	51(16)	199(60)	14(4)	2(1)	7(2)
		Yes	No	Don't know		
1. Headaches		47(14)	259(79)	14(4)		9(3)
2. Dizziness		20(6)	281(85)	16(5)		12(4)
3. Irritated Eyes		25(8)	277(84)	16(5)		12(4)
4. Irritated Nose		20(6)	280(85)	16(5)		13(4)
5. Shortness of Breath		7(2)	290(88)	18(6)		14(4)
6. Drowsiness		20(6)	279(85)	16(5)		14(4)
7. Visual Problems		9(3)	288(87)	16(5)		16(5)
8. Nausea		20(6)	279(85)	16(5)		14(4)
9. Vomiting		18(5)	280(85)	15(5)		16(5)
10. Coughing		24(7)	275(83)	16(5)		14(4)
11. Loss of Attention		21(6)	277(84)	15(5)		16(5)
12. Fatigue		23(7)	276(84)	15(5)		15(5)
13. Loss of Appetite		7(2)	287(87)	20(6)		15(5)
14. Dryness of Skin		20(6)	280(85)	16(5)		13(4)
15. Skin Irritation		15(5)	285(87)	14(4)		15(5)
16. Sore Throat		32(10)	273(83)	13(4)		11(3)
17. Tightness in Chest		8(3)	290(88)	17(5)		14(4)

(table continues)

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Table 4.2

Summary of Responses From All Schools on the Health Information Form

Item	Choice			Not responding
	No. of responses (percent of total)			
	Yes	No	Don't know	
18. Itching	26(8)	274(83)	15(5)	14(6)
19. Allergic Reactions	31(9)	270(82)	8(6)	10(3)
20. Diarrhea	14(4)	285(80)	15(5)	15(5)
21. Aching Joints	14(4)	283(86)	17(5)	15(5)
22. Problems Wearing Contact Lenses	12(4)	285(86)	17(5)	15(5)
23. Back Pain	12(4)	285(86)	17(5)	15(5)
24. Hearing Disturbances	9(3)	289(87)	16(5)	15(5)
25. Heartburn	6(2)	293(89)	16(5)	14(4)
26. Sneezing	29(9)	276(84)	13(4)	11(3)
27. Fever	20(6)	281(85)	15(5)	13(4)
28. Sinus Congestion	54(16)	253(77)	13(4)	9(3)

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Table 4.3

Results of Scoring of Responses From All Schools on the Health Information Form

	Potential sources of indoor pollutants			
Potential sources	Exist	Don't exist	Don't know	Not responding
Outdoor sources	161(10)	1423(86)	44(3)	17(1)
Indoor sources	1088(14)	6328(84)	70(1)	81(1)
All sources (or totals)	1249(14)	7751(84)	114(1)	98(1)
Sensory type symptoms	161(10)	1423(86)	44(3)	17(1)
Health-related symptoms	563(6)	7830(85)	441(5)	378(4)
All Symptoms (or totals)	769(7)	9568(85)	441(4)	408(4)

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Table 4.4

Comparison of the Existence of Potential Sources of Indoor Pollutants with Reported Symptoms for All Schools Responding to the Health Information Form

	Exist	Don't exist	Don't know	Not responding
Outdoor sources with sensory symptoms				
Sources	161(10)	1423(86)	44(3)	17(1)
Symptoms	206(10)	1738(88)	0(0)	30(2)
Outdoor sources with health-related symptoms				
Sources	161(10)	1423(86)	43(3)	17(1)
Symptoms	563(6)	7830(85)	441(5)	378(4)
Outdoor sources with all symptoms				
Sources	161(10)	1423(86)	43(3)	17(1)
Symptoms	769(7)	9568(85)	441(4)	408(4)
Indoor sources with sensory symptoms				
Sources	1088(14)	6328(84)	70(1)	81(1)
Symptoms	206(10)	1738(88)	0(0)	30(2)
Indoor sources with health-related symptoms				
Sources	1088(14)	6328(84)	70(1)	81(1)
Symptoms	563(6)	7830(85)	441(5)	378(4)

(table continues)

Table 4.4

Comparison of the Existence of Potential Sources of Indoor Pollutants with Reported Symptoms for All Schools Responding to the Health Information Form

	Exist	Don't exist	Don't know	Not responding
	Indoor sources with all symptoms			
Sources	1088(14)	6328(84)	70(1)	81(1)
Symptoms	769(7)	9568(85)	441(4)	408(4)
	All sources with sensory symptoms			
Sources	1249(14)	7751(84)	114(1)	98(1)
Symptoms	206(10)	1738(88)	0(0)	30(2)
	All sources with health-related symptoms			
Sources	1249(14)	7751(84)	114(1)	98(1)
Symptoms	563(6)	7830(85)	441(5)	378(4)
	All sources with all symptoms			
Sources	1249(14)	7751(84)	114(1)	98(1)
Symptoms	769(7)	9568(85)	441(4)	408(4)

those answering positively that sources exist (14%) and symptoms exist (7%).

A summary of the responses in terms of frequencies and percent of total for each item on the HIF for the five selected schools scoring highest is shown in Table 4.5. For the same five schools, Table 4.6 presents a summary of the frequencies, along with percent of totals for each of the four parts of the HIF and Table 4.7 presents a series of comparisons of categories of sources to categories of symptoms of indoor air pollution. The same type of statistics, but for the five selected schools scoring lowest on the HIF form, are presented in Tables 4.8, 4.9, and 4.10, respectively. Specific findings for these two groups will be presented along with findings from the case studies which will be presented next.

Case Studies

Case Study A

General Information

Demographic Data

School facility A, housing grades K-5, is 30 years old and located in a residential neighborhood in the upper piedmont of South Carolina. The facility contains four buildings connected with covered walkways and a portable classroom which was not part of this study. One of the buildings contains the cafeteria, one contains the resource center, the third contains classrooms, and the last contains classrooms, teachers' lounge and workroom, administration

Table 4.5

Summary of Responses From Five Selected Schools Scoring Highest on the Health Information Form

Part I. General Information: Potential External Sources of Indoor Pollutants

Item	Choice				Not responding
	No. of responses (percent of total)				
	Yes	No	Don't know		
1. Does the building contain asbestos?	0(0)	5(100)	0(0)		0(0)
2. Are there any "smoke stack" industries within one mile of the building?	1(20)	3(60)	0(0)		1(20)
3. Is there a creek or other open body of water adjacent to the building which is accessible to the building's occupants?	0(0)	5(100)	0(0)		0(0)
	Yes	No	Don't know		
4. Is there a land fill or garbage dump within one mile of the building?	0(0)	5(100)	0(0)		0(0)
	Well	City	County	Other	
5. What is the source of your drinking water in the building?	0(0)	5(100)	0(0)	0(0)	0(0)

(table continues)

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Table 4.5

Summary of Responses From Five Selected Schools Scoring Highest on the Health Information Form

Item	Choice			Not responding
	No. of responses (percent of total)			
Part II. Equipment Materials and Processes in the Building: Potential Internal Sources of Indoor Pollutants				
	Yes	No	Don't know	
1. Space Heaters-Kerosene:	0(0)	5(100)	0(0)	0(0)
2. Space Heaters-Natural Gas:	1(20)	4(80)	0(0)	0(0)
3. Gas Stoves:	1(20)	4(80)	0(0)	0(0)
4. Humidifiers:	0(0)	4(80)	0(0)	1(20)
5. De-Humidifiers:	0(0)	4(80)	0(0)	1(20)
6. Electronic Air Cleaners:	0(0)	4(80)	0(0)	1(20)
7. Do you have chemistry laboratories in the building?	0(0)	5(100)	0(0)	0(0)
8. Do you have home economics laboratories in the building?	0(0)	5(100)	0(0)	0(0)

(table continues)

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Table 4.5

Summary of Responses From Five Selected Schools Scoring Highest on the Health Information Form

Item		Choice			Not responding
		No. of responses (percent of total)			
		Yes	No	Don't know	
9. Do you have an industrial arts shop in your building?		1(20)	4(80)	0(0)	0(0)
10. Is smoking allowed in the building?		5(100)	0(0)	0(0)	0(0)
11. Heating:	Gas-Fired	1(20)	4(80)	N/A	N/A
	Oil-Fired	2(40)	3(60)	N/A	N/A
	Coal-Fired	0(0)	5(100)	N/A	N/A
	Electric-Powered	1(20)	4(80)	N/A	N/A
Cooling:	Gas	0(0)	5(100)	N/A	N/A
	Electrical	0(0)	5(100)	N/A	N/A
	Central Air Conditioning	2(40)	3(60)	N/A	N/A
	Room Air Conditioners	1(20)	4(80)	N/A	N/A
	None	2(40)	3(60)	N/A	0(0)
12. Does a formal maintenance program exist for the building, on paper?		4(80)	1(20)	N/A	0(0)

Item	Excellent	Average	Poor	Non-Existent	Not responding
13. What is your perception about the level of maintenance in your building?	0(0)	3(60)	1(20)	0(0)	1(20)

(table continues)

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Table 4.5

Summary of Responses From Five Selected Schools Scoring Highest on the Health Information Form

Item	Choice					Not responding
	No. of responses (percent of total)					
	Yes	No	Don't know			
14. As far as you know, are air filters changed regularly in your heating, ventilating and air conditioning units?	5(100)	0(0)	0(0)			0(0)
15. Is there mold or mildew anywhere inside the building?	1(20)	3(60)	0(0)			1(20)
	Cold		Acceptable		Hot	
	5	4	3	2	1	
1. Building Temperature	0(0)	1(20)	3(60)	0(0)	1(20)	0(0)
	Humid		Acceptable		Dry	
	5	4	3	2	1	
2. Humidity	1(20)	1(20)	2(40)	0(0)	1(20)	0(0)

(table continues)

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Table 4.5

Summary of Responses From Five Selected Schools Scoring Highest on the Health Information Form

Item	Choice					Not responding
	No. of responses (percent of total)					
	Drafty		Acceptable		Stuffy	
	5	4	3	2	1	
3. General Comfort	0(0)	1(20)	2(40)	0(0)	2(40)	0(0)
	Stale		Acceptable		Fresh	
	5	4	3	2	1	
4. Air Quality	2(40)	1(20)	1(20)	0(0)	1(20)	0(0)

(table continued)

	None		Acceptable		Strong	
	5	4	3	2	1	
5. Odor	0(0)	0(0)	3(60)	1(20)	1(20)	0(0)

(table continues)

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Table [illegible]

Summary of Responses from Five Selected Schools Scoring Highest on the Health Information Form

Item	Choice					Not responding
	No. of responses (percent of total)					
	Acceptable				Unacceptable	
	5	4	3	2	1	
6. Overall Rating of Environment	1(20)	0(0)	1(20)	2(40)	0(0)	1(20)
	Yes	No	Don't know			
1. Headaches	4(80)	1(20)	0(0)			0(0)
2. Dizziness	1(20)	4(80)	0(0)			0(0)
3. Irritated Eyes	3(60)	2(40)	0(0)			0(0)
4. Irritated Nose	3(60)	2(40)	0(0)			0(0)
5. Shortness of Breath	1(20)	3(60)	0(0)			0(0)
6. Drowsiness	4(80)	1(20)	0(0)			0(0)
7. Visual Problems	2(40)	3(60)	0(0)			0(0)
8. Nausea	2(40)	3(60)	0(0)			0(0)
9. Vomiting	2(40)	3(60)	0(0)			0(0)
10. Coughing	4(80)	1(20)	0(0)			0(0)
11. Loss of Attention	5(100)	0(0)	0(0)			0(0)
12. Fatigue	4(80)	1(20)	0(0)			0(0)
13. Loss of Appetite	1(20)	4(80)	0(0)			0(0)
14. Dryness of Skin	3(60)	2(40)	0(0)			0(0)
15. Skin Irritation	2(40)	3(60)	0(0)			0(0)
16. Sore Throat	5(100)	0(0)	0(0)			0(0)
17. Tightness in Chest	0(0)	5(100)	0(0)			0(0)
18. Itching	2(40)	3(60)	0(0)			0(0)

(table continues)

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Table 4.5

Summary of Responses From Five Selected Schools Scoring Highest on the Health Information Form

Item	Choice			Not responding
	No. of responses (percent of total)			
	Yes	No	Don't know	
19. Allergic Reactions	4(80)	1(20)	0(0)	0(0)
20. Diarrhea	1(20)	4(80)	0(0)	0(0)
21. Aching Joints	2(40)	3(60)	0(0)	0(0)
22. Problems Wearing Contact Lenses	2(40)	2(40)	1(20)	0(0)
23. Back Pain	0(0)	5(100)	0(0)	0(0)
24. Hearing Disturbances	1(20)	4(80)	0(0)	0(0)
25. Heartburn	1(20)	3(60)	1(20)	0(0)
26. Sneezing	4(80)	1(20)	0(0)	0(0)
27. Fever	1(20)	4(80)	0(0)	0(0)
28. Sinus Congestion	4(80)	1(20)	0(0)	0(0)

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Table 4.6

Results of Scoring of Responses From Five Schools Scoring Highest on the Health Information Form

Potential sources of indoor pollutants

Potential sources	Exist	Don't exist	Don't know	Not responding
	(No. of responses (percent of total)			
Outdoor sources	1(4)	24(96)	0(0)	0(0)
Indoor sources	15(13)	95(83)	4(3)	1(1)
All sources (or totals)	16(11)	119(85)	4(3)	1(1)
Sensory type symptoms	15(50)	15(50)	0(0)	0(0)
Health-related symptoms	68(49)	69(49)	2(1)	1(1)
All Symptoms (or totals)	83(49)	84(49)	2(1)	1(1)

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Table 4.7

Comparison of the Existence of Potential Source sof Indoor Pollutants with Reported Symptoms for the Five Schools Scoring Highest on the Health Information Form

	Exist	Don't exist	Don't know	Not responding
	(No. of responses (percent of total)			
Outdoor sources with sensory symptoms				
Sources	1(4)	24(96)	0(0)	0(0)
Symptoms	15(50)	15(50)	0(0)	0(0)
Outdoor sources with health-related symptoms				
Sources	1(4)	24(96)	0(0)	0(0)
Symptoms	68(49)	69(49)	2(1)	1(1)
Outdoor sources with all symptoms				
Sources	1(4)	24(96)	0(0)	0(0)
Symptoms	83(49)	84(49)	2(1)	1(1)
Indoor sources with sensory symptoms				
Sources	15(13)	95(83)	4(3)	1(1)
Symptoms	15(50)	15(50)	0(0)	0(0)
Indoor sources with health-related symptoms				
Sources	15(13)	95(83)	4(3)	1(1)
Symptoms	68(49)	69(49)	2(1)	1(1)
Indoor sources with all symptoms				
Sources	15(13)	95(83)	4(3)	1(1)
Symptoms	83(49)	84(49)	2(1)	1(1)

(table continues)

Table 4.7

Comparison of the Existence of Potential Sources of Indoor Pollutants with Reported Symptoms for the Five Schools Scoring Highest on the Health Information Form

	Exist	Don't exist	Don't know	Not responding
	(No. of responses (percent of total)			
All sources with sensory symptoms				
Sources	16(11)	119(85)	4(3)	1(1)
Symptoms	15(50)	15(50)	0(0)	0(0)
All sources with health-related symptoms				
Sources	16(11)	119(85)	4(3)	1(1)
Symptoms	68(49)	69(49)	2(1)	1(1)
All sources with all symptoms				
Sources	16(11)	119(85)	4(3)	1(1)
Symptoms	83(49)	84(49)	2(1)	1(1)

Table 4.8

Summary of Responses From Five Selected Schools Scoring Lowest on the Health Information Form

Part I. General Information: Potential External Sources of Indoor Pollutants

Item	Choice				Not responding
	No. of responses (percent of total)				
	Yes	No	Don't know		
1. Does the building contain asbestos?	0(0)	5(100)	0(0)		0(0)
2. Are there any "smoke stack" industries within one mile of the building?	0(0)	5(100)	0(0)		0(0)
	Yes	No	Don't know		
3. Is there a creek or other open body of water adjacent to the building which is accessible to the building's occupants?	0(0)	5(100)	0(0)		0(0)
4. Is there a land fill or garbage dump within one mile of thebuilding?	0(0)	5(100)	0(0)		0(0)
	Well	City	County	Other	
5. What is the source of your drinking water in the building?	1(20)	3(60)	1(20)	0(0)	0(0)

(table continues)

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Table 4.[illegible]

Summary of Responses From Five Selected Schools Scoring Lowest on the Health Information Form

Item	Choice			Not responding
	No. of responses (percent of total)			
Part II. Equipment Materials and Processes in the Building: Potential Internal Sources of Indoor Pollutants				
	Yes	No	Don't know	
1. Space Heaters-Kerosene:	0(0)	5(100)	0(0)	0(0)
2. Space Heaters-Natural Gas:	0(0)	5(100)	0(0)	0(0)
3. Gas Stoves:	0(0)	5(100)	0(0)	0(0)
4. Humidifiers:	0(0)	5(100)	0(0)	0(0)
5. De-Humidifiers:	0(0)	5(100)	0(0)	0(0)
6. Electronic Air Cleaners:	0(0)	5(100)	0(0)	0(0)
7. Do you have chemistry laboratories in the building?	0(0)	5(100)	0(0)	0(0)
8. Do you have home economics laboratories in the building?	0(0)	5(100)	0(0)	0(0)
9. Do you have an industrial arts shop in your building?	0(0)	5(100)	0(0)	0(0)

(table continues)

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Table 4.8

Summary of Responses From Five Selected Schools Scoring Lowest on the Health Information Form

Item		Choice				Not responding
		No. of responses (percent of total)				
		Yes	No	Don't know		
10. Is smoking allowed in the building?		2(40)	3(60)	0(0)		0(0)
11. Heating:	Gas-Fired	2(40)	3(60)	N/A		N/A
	Oil-Fired	0(0)	5(100)	N/A		N/A
	Coal-Fired	0(0)	5(100)	N/A		N/A
	Electric-Powered	3(60)	2(40)	N/A		N/A
Cooling:	Gas	0(0)	5(100)	N/A		N/A
	Electrical	3(60)	2(40)	N/A		N/A
	Central Air Conditioning	2(40)	3(60)	N/A		N/A
	Room Air Conditioners	0(0)	5(100)	N/A		N/A
	None	1(20)	4(80)	N/A		N/A
12. Does a formal maintenance program exist for the building, on paper?		5(100)	0(0)	N/A		0(0)
		Excellent	Average	Poor	Non-Existent	
13. What is your perception about the level of maintenance in your building?		3(60)	2(40)	0(0)	0(0)	0(0)

(table continues)

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Table 4.9

Summary of Responses From Five Selected Schools Scoring Lowest on the Health Information Form

Item	Choice					Not responding
	No. of responses (percent of total)					
	Yes	No	Don't know			
14. As far as you know, are air filters changed regularly in your heating, ventilating and air conditioning units?	5(100)	0(0)	(0(0)			0(0)
15. Is there mold or mildew anywhere inside the building?	0(0)	4(80)	1(20)			0(0)
	Cold		Acceptable		Hot	
	5	4	3	2	1	
1. Building Temperature	0(0)	0(0)	5(100)	0(0)	0(0)	0(0)
	Humid		Acceptable		Dry	
	5	4	3	2	1	
2. Humidity	0(0)	0(0)	5(100)	0(0)	0(0)	0(0)

(table continues)

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Table 4.8

Summary of Responses From Five Selected Schools Scoring Lowest on the Health Information Form

Item	Choice					Not responding
	No. of responses (percent of total)					
	Drafty		Acceptable		Stuffy	
	5	4	3	2	1	
3. General Comfort	0(0)	0(0)	5(100)	0(0)	0(0)	0(0)
	Stale		Acceptable		Fresh	
	5	4	3	2	1	
4. Air Quality	0(0)	0(0)	4(80)	0(0)	1(20)	0(0)
	None		Acceptable		Strong	
	5	4	3	2	1	
5. Odor	0(0)	0(0)	4(80)	0(0)	0(0)	1(20)
	Acceptable				Unacceptable	
	5	4	3	2	1	
6. Overall Rating of Environment	1(20)	0(0)	4(80)	0(0)	0(0)	0(0)

(table continues)

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Table 4.8

Summary of Responses From Five Selected Schools Scoring Lowest on the Health Information Form

Item	Choice			Not responding
	No. of responses (percent of total)			
	Yes	No	Don't know	
1. Headaches	0(0)	5(100)	0(0)	0(0)
2. Dizziness	0(0)	5(100)	0(0)	0(0)
3. Irritated Eyes	0(0)	5(100)	0(0)	0(0)
4. Irritated Nose	0(0)	5(100)	0(0)	0(0)
5. Shortness of Breath	0(0)	5(100)	0(0)	0(0)
6. Drowsiness	0(0)	5(100)	0(0)	0(0)
7. Visual Problems	0(0)	5(100)	0(0)	0(0)
8. Nausea	0(0)	5(100)	0(0)	0(0)
9. Vomiting	0(0)	5(100)	0(0)	0(0)
10. Coughing	0(0)	5(100)	0(0)	0(0)
11. Loss of Attention	0(0)	5(100)	0(0)	0(0)
12. Fatigue	0(0)	5(100)	0(0)	0(0)
13. Loss of Appetite	0(0)	5(100)	0(0)	0(0)
14. Dryness of Skin	0(0)	5(100)	0(0)	0(0)
15. Skin Irritation	0(0)	5(100)	0(0)	0(0)
16. Sore Throat	0(0)	5(100)	0(0)	0(0)
17. Tightness in Chest	0(0)	5(100)	0(0)	0(0)
18. Itching	0(0)	5(100)	0(0)	0(0)
19. Allergic Reactions	0(0)	5(100)	0(0)	0(0)
20. Diarrhea	0(0)	5(100)	0(0)	0(0)
21. Aching Joints	0(0)	5(100)	0(0)	0(0)
22. Problems Wearing Contact Lenses	0(0)	5(100)	0(0)	0(0)

(table continues)

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Table 4.8

Summary of Responses From Five Selected Schools Scoring Lowest on the Health Information Form

Item	Choice		Not responding	
	No. of responses (percent of total)			
23. Back Pain	0(0)	5(100)	0(0)	0(0)
24. Hearing Disturbances	0(0)	5(100)	0(0)	0(0)
25. Heartburn	0(0)	5(100)	0(0)	0(0)
26. Sneezing	0(0)	5(100)	0(0)	0(0)
27. Fever	0(0)	5(100)	0(0)	0(0)
28. Sinus Congestion	0(0)	5(100)	0(0)	0(0)

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Table 4.9

Results of Scoring of Responses From Five Schools Scoring Lowest on the Health Information Form

Potential sources of indoor pollutants				
Potential sources	Exist	Don't exist	Don't know	Not responding
	(No. of responses (percent of total)			
Outdoor sources	1(4)	24(96)	0(0)	0(0)
Indoor sources	4(3)	111(97)	0(0)	0(0)
All sources (or totals)	5(4)	135(96)	0(0)	0(0)
Sensory type symptoms	0(0)	29(97)	0(0)	1(3)
Health-related symptoms	0(0)	140(100)	0(0)	0(0)
All symptoms (or totals)	0(0)	169(99)	0(0)	1(1)

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Table 4.10

Comparison of the Existence of Potential Sources of Indoor Pollutants with Reported Symptoms for the Five Schools Scoring Lowest on the Health Information Form

	Exist	Don't exist	Don't know	Not responding
	(No. of responses (percent of total)			
Outdoor sources with sensory symptoms				
Sources	1(4)	24(96)	0(0)	0(0)
Symptoms	0(0)	29(97)	0(0)	1(3)
Outdoor sources with health-related symptoms				
Sources	1(4)	24(96)	0(0)	0(0)
Symptoms	0(0)	140(100)	0(0)	0(0)
Outdoor sources with all symptoms				
Sources	1(4)	24(96)	0(0)	0(0)
Symptoms	0(0)	169(99)	0(0)	1(1)
Indoor sources with sensory symptoms				
Sources	4(3)	111(97)	0(0)	0(0)
Symptoms	0(0)	29(97)	0(0)	1(3)
Indoor sources with health-related symptoms				
Sources	4(3)	111(97)	0(0)	0(0)
Symptoms	0(0)	140(100)	0(0)	0(0)
Indoor sources with all symptoms				
Sources	4(3)	111(97)	0(0)	0(0)
Symptoms	0(0)	169(99)	0(0)	1(1)

(table continues)

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Table 4.10

Comparison of the Existence of Potential Sources of Indoor Pollutants with Reported Symptoms for the Five Schools Scoring Lowest on the Health Information Form

	Exist	Don't exist	Don't know	Not responding
	(No. of responses (percent of total)			
All sources with sensory symptoms				
Sources	5(4)	135(96)	0(0)	0(0)
Symptoms	0(0)	29(97)	0(0)	1(3)
All sources with health-related symptoms				
Sources	5(4)	135(96)	0(0)	0(0)
Symptoms	0(0)	140(100)	0(0)	0(0)
All sources with all symptoms				
Sources	5(4)	135(96)	0(0)	0(0)
Symptoms	0(0)	169(99)	0(0)	1(1)

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offices, and combination boiler and storage room. All of the buildings contain washrooms, some of which open directly into the classrooms.

The average number of occupants using the facility, as reported by the principal, was 300 students, 22 teachers, and 15 staff. The visit was made on March 17, 1986, from 1:00 to 3:30 PM. The facility is in the same county as the buildings in Case Studies C, G, I, and J.

General Description of the Building

The buildings are all one story in height, sit on slab-on-grade foundations, and have built-up finish flat roofs. The exterior walls are constructed of concrete block, covered with a brick veneer. There are metal frame windows and doors. There are no garages attached to the buildings.

The interior floors are concrete over which has been placed floor tile and in some locations, carpet. The ceilings are exposed steel decking which has been painted. The interior walls are constructed of concrete block which also has been painted.

The buildings are heated by a hot water distribution system. The oil-fired boiler and related controls are located in the boiler room which opens only to the outdoors. The boiler has its own ventilation to the outdoors through the exterior wall. The heating system is 30 years old. Thermostats are located in every room in which students and/or teachers' use within the facility. The buildings are not air conditioned. A few of the rooms, however, have

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window air conditioning units. They are five years old. There are no exhaust air vents in any of the rooms. Any air exchange is solely through openings in the walls.

The kitchen houses refrigeration, cooking, and food preparation equipment. The propane gas stove has its own ventilator which exhausts air to the outdoors at the roof level. There is no other special mechanical ventilation in the buildings.

The fresh water is obtained from the city. Hot water is obtained from a gas-fired heater located in the boiler room. It has its own exhaust vent to the outdoors through the exterior wall. The waste water is disposed to the city sewer system. The washrooms and kitchen contain the conventional types of plumbing fixtures. There are sinks in some of the classrooms and drinking fountains in the hallways. Most of the rooms have fluorescent lighting. The others have incandescent lighting.

The teachers' workroom contains a liquid-process copy machine. The furniture within the buildings is constructed of wood, plastic, and/or metal.

Health Information Form Data

The score on the HIF was 24 which placed this facility in the group having a high potential of problems with indoor air pollution. A summary of the responses from the form indicated the following:

1. There are no visible exterior sources of outdoor pollutants.

2. Relative to interior materials, equipment, and activities that might cause indoor air pollution, smoking is allowed (but only in a special room off the cafeteria) and there is an oil-fired boiler.

3. In terms of reported sensory information, the interior environment is marginally acceptable in that it is somewhat cold, humid, and drafty. Furthermore, the air quality is somewhat stale, there are objectionable odors, and the overall rating of the environment is generally not acceptable.

4. Sixteen of the 28 possible health-related symptoms were reported by the occupants of the buildings.

5. Absences were greatest due to flu and colds during February, 1986.

Results of Building Inspection

The following is a summary of the results of the inspection of the buildings' exterior, cafeteria and kitchen, resource center, teacher workroom and lounge, and two classrooms (one in each building that contained classrooms). The Comprehensive Building Survey and Room Survey Forms were used in the inspection process.

Building Exterior

The exterior grounds and finishes were in fair condition. Some of the building surfaces needed cleaning. There were no visible sources of outdoor pollutants. The quality of air was good. The roof vents appeared in good condition.

Building Interior

The condition of the floors, walls, and ceilings in all the rooms inspected was good. No moisture problems were found except in the boiler room. The floor was discolored where the overflow line from the boiler emptied into the floor drain. The damage was only minor.

Generally there were no offensive odors. The cafeteria was somewhat musty smelling and the boiler room had an odor of oil. The air quality was stale to acceptable. The general comfort of the buildings was stuffy.

The condition of the mechanical, plumbing, and electrical equipment, fixtures, and auxiliary items such as vents and pipes were fair with the exception of the boiler which was in poor condition. The intensity of the lighting was good to fair.

All toxic substances such as cleaning fluids are kept in a storage room off the boiler room. This room is kept locked. Small amounts of cleaning agents were kept in some of the rooms in the buildings, which are inaccessible to the students. Duplication fluid are stored in the teachers' workroom which also is inaccessible to the students and appeared to be adequately ventilated.

There were no activities occurring in the buildings at the time of the visit which would cause indoor air pollution. All the equipment and furnishings, known to be potential sources of indoor air contaminants were ventilated and maintained so as not to cause health-related problems. The remaining equipment and furnishings were not considered to be potential sources of indoor air quality problems.

Results from Interviews

The principal indicated that problems do not generally exist with the quality of the indoor air. Relative to the sixteen health-related symptoms reported on the HIF, the principal felt that some of the causes could be traced to the home environment, some from personal chronic health problems such as sinus congestion, and others from minor infectious diseases. The teachers interviewed agreed with the principal.

All housekeeping activities are performed after classes have been dismissed for the day. The exceptions are for emergencies and after lunch in the cafeteria and kitchen. Major maintenance activities such as insecticide treatment, painting, and floor waxing are performed when classes are not in session such as on the weekends and during school holidays. There have not been any building renovations or energy conservation projects performed within the last ten years.

Results of Environmental Measurements

The following environmental measurements were taken in some of the rooms inspected. The locations of the measurements were arbirarily selected.

1. Five temperatures were taken. They ranged from [illegible]°F to 75°F, with a mean of 74°F.

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and/or teachers' use within the facility. The buildings are not air conditioned. A few of the rooms, however, have window air conditioning units. They are five years old. There are no exhaust air vents in any of the rooms. Any air exchange is solely through openings in the walls.

The kitchen houses refrigeration, cooking, and food preparation equipment. The propane gas stove has its own ventilator which exhausts air to the outdoors at the roof level. There is no other special mechanical ventilation in the buildings.

The fresh water is obtained from the city. Hot water is obtained from a gas-fired heater located in the boiler room. It has its own exhaust vent to the outdoors through the exterior wall. The waste water is disposed to the city sewer system. The washrooms and kitchen contain the conventional types of plumbing fixtures. There are sinks in some of the classrooms and drinking fountains in the hallways. Most of the rooms have fluorescent lighting. The others have incandescent lighting.

The teachers' workroom contains a liquid-process copy machine. The furniture within the buildings is constructed of wood, plastic, and/or metal.

Health Information Form Data

The score on the HIF was 24 which placed this facility in the group having a high potential of problems with indoor

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specified by ASHRAE. The relative humidities, however, were slightly low. According to ASHRAE, they should all be above 30%. The dry environment attributed to the stuffy feeling and stale quality of air. This was especially the case in the rooms containing the higher concentrations of carbon dioxide.

The air exchange rate based on the mean concentration of carbon dioxide (920 ppm) was about 18 cfm per person. This is above the minimum recommended rate under both the current ASHRAE standards of 5 cfm per person and 15 cfm per person for rooms in which smoking is not allowed. Two rooms, however, had concentrations of carbon dioxide above 1000 ppm. At and above this level, objectionable odors become more noticeable. Also the corresponding air exchange rate of 15.5 cfm per person is marginally acceptable under the proposed ASHRAE standards.

The level of maintenance appeared to be good. In discussions with the principal and teachers it was apparent that they were not aware of the problems with indoor air pollution. They were interested in learning more about it.

Recommendations

The relative humidity of the entire facility should be maintained above 30%. This can be attained by adding moisture to the air such as with humidifiers. If they are used they must be maintained in accordance with manufacturer's recommendations so they do not become a source of indoor air pollution. Since the comfort of the building is effected by the combination of temperature and relative humidity, it is recommended that a ventilation specialist be consulted to make the appropriate changes. While analyzing the temperatures and humidities, the specialist should also consider ways of maintaining an air exchange rate at or above 15 cfm per person in all the rooms where smoking is not allowed and 60 cfm per person in smoking-allowed rooms.

Finally, it is recommended that the teachers and staff be provided with useful information on indoor air pollution and its health-related affects. They need to become aware of what causes it and how to prevent it.

Case Study B

General Information

Demographic Data

School building B, housing grades K-2, is nine years old and located in a residential neighborhood in the coastal plain of South Carolina within five miles of the Atlantic Ocean. The building contains classrooms, two teachers' lounges, teacher workroom, administration office, cafeteria and kitchen, theater, computer room, library, resource center, music room, art room, mechanical room, storage room, janitor closets and washrooms.

The average number of occupants of the building, as reported by the principal, was 870 students, 45 teachers, and 12 staff. The visit took place on March 21, 1987, from 1:00 to 3:30 PM.

General Description of the Building

The building is one story in height, sits on a slab-on-grade foundation, and has a built-up finish flat roof. The exterior walls are constructed of concrete block, covered with a brick veneer. There are metal frame windows and doors. There is not a garage attached to the building.

The interior floors are concrete over which has been placed a variety of finishes. These include terrazzo, carpet, and vinyl floor tile. The ceilings are drop-type which integrate acoustical panels with the lighting and supply and exhaust air fans. The interior walls are constructed of concrete block which has been painted, and drywall (painted) supported by steel studs. Some of the classrooms open to both the outdoors and interior corridors.

The building is heated and cooled by electric-powered heat pumps which are located on the roof. The system is the same age as the building. The fresh air is brought into the building from the roof level and exhausted below the roof through the exterior walls. The temperature is controlled by thermostats located in all the rooms except janitor closet, mechanical room, and storage room.

The kitchen contains refrigerator, cooking, and food preparation equipment. The electric stoves have their own ventilators which exhaust air to the outdoors at the roof level. There is no other special mechanical ventilation in the building.

The fresh water is obtained from the city. Hot water is obtained from an electric-powered heater located in the mechanical room. The waste water is disposed into the city sewer system. The kitchen and washrooms contain conventional types of plumbing fixtures. There are washrooms off some of the classrooms. There are sinks in some of the classrooms, one of the janitor's closet, and teacher lounges. There are drinking fountains in the hallways.

All rooms have fluorescent lighting. There are liquid-process copying machines in the teachers' workroom. The teacher lounges contain a soda machine, vending machine, and refrigerator. All the furniture is constructed of wood, plastic, and/or metal.

Health Information Form Data

The score on the HIF was 21 which placed this building in the group having a high potential of problems with indoor air pollution. A summary of the responses from the form indicated the following:

1. There are no visible exterior sources of outdoor air pollutants.

2. Relative to interior materials, equipment, and activities that might cause indoor air pollution, smoking is allowed (but only in one of the teachers' lounges) and central air conditioning exists.

3. In terms of the reported sensory information, the interior environment is acceptable.

4. Nineteen of the 28 possible health-related symptoms were reported by the building's occupants.

5. Information was not provided on absences.

Results of Building Inspection

The following is a summary of the results of the inspection of the buildings' exterior, both teacher lounges, teacher workroom, janitor storage room, cafeteria, mechanical room, and four classrooms. The Comprehensive Building Survey and Room Survey Forms were used in the inspection process.

Building Exterior

The exterior grounds and material finishes were in good condition. There were no visible sources of outdoor air pollution. The quality of the air was good. The rooftop mechanical equipment and vents also appeared to be in good condition.

Building Interior

The condition of the floors, walls, and ceilings in all the rooms inspected were good. No moisture problems were observed except a small amount of staining below the hot water heater. This appeared to be only a minor problem.

There were no offensive odors. The air quality and general comfort of the building was acceptable. All mechanical, electrical, and plumbing equipment, fixtures, and auxiliary items such as vents and pipes were in good condition. The intensity of lighting was good in all the rooms inspected.

All toxic chemicals such as cleaning agents were contained in the janitor's storage room which is inaccessible to the students. This room was well ventilated. Small amounts of cleaning agents were kept in the janitor closets, kitchen, and teacher lounges. All of these rooms were well monitored and ventilated. Duplication fluid for the copying machines was stored in the teachers' workroom which is also inaccessible to the students.

There were no activities occurring in the building at the time of the visit which would cause indoor air pollution. All equipment and furnishings known to be potential sources of indoor air contaminants were well ventilated and adequately maintained so as not to cause health-related problems. The remaining equipment and furnishings were not considered to be potential sources of indoor air quality problems.

Results from Interviews

The principal indicated that there were no problems with the quality of the indoor air. Relative to the 19 health-related symptoms reported on the HIF the principal felt that some of the causes stem from the home environment, some from individual chronic health problems such as sinus congestion, and others from minor infectious diseases. The teachers interviewed agreed with the principal. One of the teachers indicated there have been problems with objectionable odors in the washroom off her classroom. This only occurs on some days. She attributed it to poor ventilation in the washrooms.

All housekeeping activities are performed after classes have been dismissed for the day. The exceptions are for emergencies and after lunch in the cafeteria and kitchen.

Major maintenance tasks such as painting, insecticide treatment, and floor waxing are performed on weekends or during school holidays. There have been no major building renovations or energy conservation projects performed since the building was constructed.

Results of Environmental Measurements

The following environmental measurements were taken in some of the rooms inspected. The locations of the measurements were arbitrarily selected.

1. Seven temperatures were taken. They ranged from 72°F to 74°F, with a mean of 73°F.

2. Seven relative humidities were taken. They ranged from 30% to 44%, with a mean of 34%.

3. Two radon monitors were placed in the building. The concentrations were 1.3 pC/1 and 1/8 pC/1, with a mean of 1.55 pC/1.

4. Two formaldehyde monitors were placed in the building. The concentrations were 0.025 ppm and 0.040 ppm, with a mean of 0.033 ppm.

5. Five air samples were taken to determine the concentration of carbon dioxide. The levels ranged from 400 ppm to 750 ppm, with a mean of 610 ppm.

Findings

There does not appear to be any problems with the quality of the indoor air. This is supported by the statements of the principal and teachers and the results of the inspection. There does not appear to be a strong relationship between the sources and causes of indoor air pollution and health-related symptoms as reported on the HIF. There was some confusion in completing the HIF relative to the cause(s) of the health-related symptoms as determined in the interview. The other information on the form was verified during the inspection.

The concentrations of radon and formaldehyde were all below the threshold levels for the respective contaminant. The range of temperatures and humidities were within the acceptable ranges specified by ASHRAE. The air exchange rate, based on the mean concentration of carbon dioxide (610 ppm) is 37 cfm per person. This is above the recommended minimum rate as stipulated by both the current (5 cfm per person) and proposed (15 to 20 cfm per person) ASHRAE standard for nonsmoking areas. Even the highest carbon dioxide concentration of 750 ppm (or 25 cfm per person) is acceptable.

The level of maintenance appeared to be good. In discussions with the principal and teachers, it was apparent that they were not aware of the problems with indoor air pollution. They were interested in learning more about it.

Recommendations

The interior environment is being maintained adequately and no changes are needed at this time. It is recommended that the teachers and staff be provided with usable information on indoor air pollution and its health-related affects. They need to become aware of what causes it and how to prevent it.

Case Study C

General Information

Demographic Data

School facility C, housing K-5, is 26 years old and located in a rural environment in the upper piedmont of South Carolina. The facility contains three buildings connected with covered walkways and four portable classrooms which were not included in this study. Two of the three buildings contain classrooms, some of which contain washrooms. Some of the classrooms are interconnected in groups of three so that the occupants can move from one to another without going outdoors. The remaining classrooms are open only to the outdoors.

The third building contains the administrative offices, teacher workroom, general storage room, cafetorium (including kitchen), physical education equipment storage room (also used by some of the staff for a lounge), boiler room, and washrooms. The average number of occupants using the facility as reported by the principal, was 448 students, 18 teachers, and 21 staff. The visit was made on March 12, 1987, from 1:00 to 3:30 PM. This facility is located in the same county as those in Case Studies A, G. I, and J.

General Description of the Buildings

The buildings are all one-story in height, sit on slab-on-grade foundations, and have built-up finish flat roofs.

The exterior walls are constructed of concrete block, covered with a brick veneer. There are metal frame windows and doors. There is no garage attached to the building.

The interior floors are concrete over which has been placed floor tile and in some locations carpet. The ceilings are drop-type with painted panels. The interior walls are constructed of concrete block which have been painted.

The buildings are heated by a hot water distribution system. The gas-fired boiler and related controls are located in the boiler room which is ventilated to the outdoors. The system is 26 years old. Thermostats, used to control the heat, are located in all the rooms except the groups of interconnected classrooms. In this case there is one thermostat for each group. All rooms except the teachers' workshop and storage rooms contain window air conditioning units. These are about one year old. There are exhaust air vents located in the ceilings of all the rooms. The stale air is exhausted to the outdoors of the roof level.

The cafetorium has a separate mechanical ventilating system. The air handling units are located on the roof of the building and controlled in the cafetorium. There is a kitchen adjacent to the cafetorium which houses refrigeration, cooking, and food preparation equipment. The gas stoves have their own ventilators which exhaust the air to the outdoors of the roof level. There does not exist any other special mechanical ventilation equipment in the building.

The fresh water is obtained from the city. Hot water is obtained from a gas-fired heater located in the boiler room. It has its own exhaust vent to the outdoors at the roof level. The waste water is disposed to a septic system which is on the school property. The washrooms and kitchen contain the conventional types of plumbing fixtures. There are sinks in some of the classrooms and a drinking fountain in the hallway of the building containing the cafetorium. There is fluorescent lighting in all the rooms.

The teacher's workroom contains three liquid-processing copying machines. There is also a portable floor fan in this room. The furniture within the building is constructed of wood, plastic, and/or metal.

Health Information Form Data

The score on the HIF was 20 which placed this facility in the group having a high potential of problems with indoor air pollution. A summary of the responses from the form indicated the following:

1. There are no visible exterior sources of outdoor air pollutants.

2. Relative to interior materials, equipment, and activities that might cause indoor air pollution, the heating system is oil-fired, faculty are allowed to smoke (but only within the teachers' workroom), and window air conditioning units exist.

3. In terms of the reported sensory information, the interior environment is acceptable.

4. Seventeen of the 28 possible health-related symptoms were reported by the occupants of the building.

5. Absences were greatest due to flu in January, 1986.

Results of Building Inspection

The following is a summary of the results of the inspection of the buildings' exterior, cafetorium, store room, teachers' workroom, boiler room, and four classrooms (two in each classroom building). The Comprehensive Building Survey and Room Survey Forms were used in the inspection process.

Building Exterior

The exterior grounds and material finishes were in good to fair condition. There were no visible sources of outdoor air pollutants. The quality of air was good. The rooftop vents and air handling units appeared to be in good condition. There was a minor amount of water damage on the exterior surface of the brick. But this was only a cosmetic problem in that it was not indicative of any major structural problems.

Building Interior

The condition of the floors, walls, and ceiling in all the rooms inspected were good to fair. No moisture problems were found except in the boiler room. The floor was discolored where the condensate line from the boiler emptied into the floor drain. This was caused by a backup in the floor drain line.

There were no offensive odors. Some of the classrooms contained deodorizers apparently to mask some localized odors. The air quality was generally acceptable except in the storage room and teachers' workroom. There it was somewhat stale. The general comfort in the buildings was acceptable to stuffy.

The condition of the mechanical, plumbing, and electrical equipment, fixtures, and auxiliary items such as vents and pipes was fair to good. The intensity of lighting was good in all rooms.

Toxic substances such as cleaning fluids were stored either in a small room off the boiler room or in a closet off the kitchen. Both rooms were kept locked when not being used and were fairly well ventilated. A small amount of duplication fluid was stored in the teacher's workroom. There were no activities occurring in the building at the time of the visit which would cause indoor air pollution. It appeared that the floor fan was used to ventilate the teachers' workroom when the copying machines were being used. All the equipment and furnishings known to be potential sources of indoor air contaminants were well ventilated and adequately maintained so as not to cause health-related problems. The remaining equipment and furnishings were not considered to be potential sources of indoor air quality problems.

Results from Interviews

The principal stated that there have not been any continuous problems with the quality of the indoor air. There have been instances of children, having objectionable body odors coming to school resulting in air quality problems. On one occasion, the septic system caused a backup of waste water into the buildings which produced both odor and air quality problems. The carpets had to be replaced following this event.

At times some of the classrooms and offices become too hot and the windows and/or doors must be opened or window air conditioning units turned on to lower the room temperature. Two of the teachers indicated problems with the quality of the air in the washrooms off the classrooms (which are poorly vented).

The principal noted that all housekeeping activities are performed after the classes end for the day. The only exception is in cases of emergencies and routine tasks that must be done prior to and after lunch in the cafetorium. Major maintenance activities such as insecticide treatment, painting, and similar tasks are performed when classes are not in session, such as on weekends. There have not been any building renovations or energy conservation projects within the past ten years. Finally, the principal noted that the school is planned to be permanently closed in two years.

Results of Environmental Measurements

The following environmental measurements were taken in some of the rooms inspected. The locations of the measurements were arbitrarily selected.

1. Four temperatures were taken. They ranged from 70°F to 75°F, with a mean of 73°F.

2. Four relative humidities were taken. They ranged from 25% to 35%, with a mean of 29%.

3. Two radon monitors were placed in the facility. The concentrations were 0.7 pC/1 and 5.7 pC/1, with a mean of 3.2 pC/1.

4. Two formaldehyde monitors were placed in the facility. The concentrations were 0.015 ppm and 0.032 ppm, with a mean of 0.024 ppm.

5. Four air samples were taken for concentrations of carbon dioxide. The levels ranged from 300 ppm to 1700 ppm, with a mean of 875 ppm. The levels in the classrooms were the highest, 1000 ppm to 1700 ppm.

Findings

There does not appear to be an overall problem with the quality of the indoor air. This is supported by the statements of the principal and teachers; along with the results of the inspection. The HIF does not show any strong relationship between causes of sources of indoor air pollution and reported health-related symptoms. The existence of a gas stove was not noted on the form. The other information on the form was verified during the inspection.

All concentrations of formaldehyde were below the threshold level. The existence of a gas stove was not noted on the form. The other information on the form was verified during the inspection.

All concentrations of formaldehyde were below the threshold level. The same held true for the mean concentration of radon. However, one monitor (placed in the storage room) indicated a concentration of radon (5.7 pC/1) that exceeded the lowest acceptable level (5.0 pC/1) specified by the Environmental Protection Agency (EPA). In this case the building should be monitored for the contaminant over a year's time in accordance with EPA guidelines. Such a low concentration of radon would not be causing the reported health-related symptoms.

The range of temperatures were acceptable. This were generally not the case for the relative humidities. According to ASHRAE recommended guidelines, the minimum relative humidity for the existing temperatures is 30%. Many of the rooms had humidities lower than this. This could be causing some of the reported health-related symptoms.

The mean air exchange rate of 19 cfm per person based on the mean concentration of carbon dioxide (875 ppm) is acceptable according to current ASHRAE standards (minimum of 5 per person in nonsmoking areas). This would also hold true for the proposed changes to the standard (minimum off 15 cfm per person for nonsmoking areas). However, in those rooms where the concentrations are over 1000 ppm, potential problems exist. First odors are more detectable at levels above 1000 ppm. This was the case for the rooms in which the concentrations of carbon dioxide exceeded this level according to the teachers. Second, the level of carbon dioxide corresponding to the minimum proposed ASHRAE standard of 1050 ppm is exceeded in one of the classrooms.

The level of maintenance appeared to be good. In discussions with the principal and teachers, it was apparent that they were not aware of the problems with indoor air pollution. They had heard of radon but didn't know how to go about determining if it existed in their building and what to do if it did. They were interested in learning more on the subject.

Recommendations

All of the recommendations made herein assume that the facility will be continued to be used. The humidity levels within the facility should be increased above 30%. This can be done with humidifiers. However, they must be maintained in accordance with the manufacturer's recommendations. If they are not, problems from indoor air pollution can occur.

The rate of air exchange should be increased to a minimum of 15 cfm per person in nonsmoking areas and 60 cfm per person in ares where smoking is allowed. This will reduce if not eliminate any odor problems and improve the quality of the air and comfort of the environment. A ventilation specialist should be consulted to perform this activity.

Relative to the radon, it is recommeded that the room no longer be used as a lounge or meeting room for the staff. Further monitoring should be performed in accordance with EPA recommendations especially if the building is to be continued to be used. If further monitoring indicates a longer-range problem, appropriate actions should be taken utilizing experienced personnel.

It is also recommended that the teachers and staff be provided with useful information of indoor air pollution and its effects. They need to become aware of what causes it and how they can prevent it.

Case Study D

General Information

Demographic Data

School building D is 32 years old and located in a residential area in the coastal plain of South Carolina within 50 miles of the Atlantic Ocean. The building which houses the second and third grades is one of a series of classroom facilities used for the elementary school classes on this site. Besides the classrooms the building contains washrooms, a speech therapy office, a workroom, and a janitor closet. The average number of occupants in the building, as reported by the principal, was 350 students, 14 teachers, and 4 staff. The visit took place on March 18, 1987, from 9:00

to 11:00 AM. This school is located in the same city as the one in Case Study H.

General Description of the Building

The building is one-story in height, sits on a slab-on-grade foundation and has a built-up finish flat roof. The exterior walls are constructed of concrete block, covered with a brick veneer. There are metal-frame windows and doors. Some of the glass window panes have been removed and replaced with plastic panels. There is no garage attached to the building.

The interior floors are concrete over which has been placed floor tile and in some locations, carpet. The ceilings are drop-type with acoustical panels. The interior walls are constructed of concrete block which has been painted.

The building is heated and cooled by electric-powered heat pumps which are located on the roof. The system is eight years old. The temperature is controlled by thermostats located in every third or fourth room. The air supply and exhaust vents are located on the interior (hall) walls within two feet of each other. The fresh air enters the building at the roof level. The exhaust air leaves the buildings at the same level but not in the same proximity as the fresh air vents. There is no special mechanical ventilation for any of the rooms in the building.

Fresh water is obtained from the city. Waste water is disposed into a city sewer system. The building does not have hot water. The washrooms contain the typical kinds of plumbing fixtures and there are sinks in some of the classrooms and one in the workroom. There are drinking fountains in the hallway. All rooms have fluorescent lighting.

The building does not contain any types of appliances. The cafeteria is located in another building. There were two portable electric heaters in the classrooms. A liquid-process copying machine and drip-type coffee maker are located in the workroom. The office and classroom furniture are constructed of wood, plastic, and/or metal.

Health Information Form Data

The score on the HIF was 18 which placed this building in the group having a high potential of problems with indoor air pollution. A summary of the responses from the form indicate the following:

1. There are no visible exterior sources of outdoor air pollutants.

2. Relative to interior materials, equipment, and activities that might cause indoor air pollution, central air conditioning exists and mold or mildew is present.

3. In terms of the reported sensory information, the interior environment is generally not acceptable. The form indicates a dry humidity, stuffiness, stale air quality, and a strong odor.

4. Eleven of the 28 possible health-related symptoms were reported by the building's occupants.

5. Absences were greatest due to colds during February and March, 1986.

Results of Building Inspection

The following is a summary of the results of the inspection of the building's exterior, four classrooms, speech therapy office, workroom, and hallway. The Comprehensive Building Survey and Room Survey Forms were used in the inspection process.

Building Exterior

The exterior grounds and material finishes were in good to fair condition. There did not appear to be any water damage on the exterior of the structure. There were no visible sources of outdoor air pollutants. The quality of air was good. The rooftop heat pumps and vents appeared to be in good working condition.

Building Interior

The condition of the floors, walls, and ceilings were good to fair. An exception to this was in the hallway where there was visible evidence of settlement of the slab. There was some evidence of moisture problems in the workroom and one of the classrooms. In the first case it was below the sink. In the classroom it was located on the lower portion of an exterior wall. There was a distinct moldy odor throughout the building. Some of the rooms had deodorizers in them. The carpets did not smell moldy in those areas tested. The general comfort of the building was acceptable to somewhat stuffy.

All mechanical, electrical and plumbing equipment, fixtures, and auxiliary items such as vents and pipes were in good to fair condition. The supply and exhaust air vents within each room are located too close to each other. This results in a nonuniform air mix and ineffective air exchange rate. The intensity of lighting is adequate.

There were no large quantities of harmful substances stored in the building. Small amounts of cleaning solutions, duplication fluid, and art supplies were found in the workroom. This room was reasonably organized and free from any major health hazards. The janitor closet also contained small quantities of cleaning agents. This room is kept locked.

There were no activities occurring in the building at the time of the visit which would cause indoor air pollution. All the equipment and furnishings known to be potential sources of indoor air contaminants were well ventilated and adequately maintained so as not to cause health-related problems. The remaining equipment and furnishings were not considered to be potential sources of indoor air quality problems.

Results from Interviews

The principal indicated that there have been and continues to be problems with the health of some of the teachers and students. The type of problems described were mainly upper-respiratory in nature. When the people were not in the building for relatively long periods of time such as the weekend or when assigned to another building, the problems disappeared.

The building sustained a major fire in 1979. Furthermore, the facility has been flooded in the past. The carpets were replaced following the last flood. The principal also noted that the building was constructed on or close to a large sawdust storage area.

Many of the teachers who work in the building substantiated the data noted by the principal. One of the teachers was hoping that this inspector would be taking mold cultures so she could get results of them and provide the information to her doctor as part of a diagnosis for her health problems. Help has been requested from local and state health agencies without success.

The principal indicated that all housekeeping was performed after school hours except in cases of emergency. Major maintenance activities such as waxing floors, painting, and treating for insects are done on weekends or during school holidays. There have not been any building renovations or energy conservation projects performed within the last decade.

Results of Environmental Measurements

The following environmental measures were taken in some of the rooms inspected. The locations of the measurements were arbitrarily selected.

1. Six air temperatures were taken. They ranged from 67°F to 71°F, with a mean of 70°F.

2. Six relative humidities were taken. They ranged from 45% to 51%, with a mean of 47%.

3. Two radon monitors were placed in the building. The concentrations were 0.9 pC/1 and 1.2 pC/1, with a mean of 1.05 pC/1.

4. Two formaldehyde monitors were placed in the building. The concentrations were 0.051 ppm and 0.059 ppm, with a mean of 0.055 ppm.

5. Five carbon dioxide test samples were taken. The concentrations ranged from 1600 to 2200 ppm, with a mean of 1940 ppm.

Findings

There is definitely a problem with the quality of the indoor air in the building. This is supported by the statements of the principal and teachers along with the moldy odor in the building. The cause does not appear to be related to the materials of which the building is constructed, the activities which were occurring within it or the condition of the air handling system. The HIF does not show any strong relationship between causes or sources of indoor air pollution and reported health-related symptoms. The items contained on the HIF were verified during the inspection.

The concentrations of radon and formaldehyde were both below their respective threshold levels. The temperatures and relative humidities were acceptable; however, the latter were on the dry side. The evidence of moisture problems on the wall in the classroom was a localized problem and did not appear to be contributing to the indoor air problems. Based on the mean carbon dioxide concentration, the air exchange rate is 6.5 cfm per person which is considered low, but marginally acceptable by current ASHRAE standards for nonsmoking areas (minimum of 5.0 cfm per person). For the highest concentrations of 2200 ppm of carbon dioxide the corresponding air exchange rate of 5.6 cfm per person also meets the noted standard. However, these rates are severely inadequate under the proposed changes which would specify a minimum of 15 cfm per person (1050 ppm) in rooms where smoking is not allowed. Also at carbon dioxide concentrations of 1000 ppm or greater, odors are more noticeable. The results of both the relative humidity and carbon dioxide measurements substantiate the feeling of dryness and stuffiness as reported in the HIF, along with the existence of of objectionable odors.

In discussions with the principal and teachers it was apparent that they knew very little about indoor air pollution and the effects it can have on one's health. All they knew was there existed a health problem and they needed help to find the cause. Furthermore, there appeared to be little concern by the personnel in the school district central office and the local and state health departments to determine the cause of the problem and take steps to alleviate it. This is caused by a lack of awareness of the potential seriousness of indoor air pollution and the unavailability of useful technology and methodology to diagnose, alleviate, and even prevent problems from indoor air contaminants. Finally, the level of maintenance appeared to be good.

Recommendations

Further study of the air quality is needed. It appears that one or more types of mold and/or fungus exist. Following the visit to this school, specially prepared petri dishes were supplied to the principal to obtain mold/fungus cultures. These were returned for review by personnel in the Microbiology Department at Clemson University. The preliminary findings, based on examination only, indicated a relatively high amount of molds and/or fungus. Since this is a state-owned facility, the local and/or state health department should be contacted, informed of the findings of this study, and requested to follow-up on the problem. It is their responsibility to determine the specific problem(s) and solutions.

Once the contaminants are known, the next step would be to determine the cause(s). If it is mold or fungus, as suspected, its source could be in the carpet, coming in up from below the slab, or in the ventilation system (probably ducts). After the sources are located, resources should be dedicated to alleviate the cause(s) using trained and experienced personnel and methods which would have proven to be successful. The cause(s) of the moisture problems on the walls should also be determined and steps taken to alleviate the condition.

It is also recommended that the rate of air exchange be increased to a minimum of 15 cfm per person. This will reduce, if not eliminate, any odor problems. This is especially critical since the supply and exhaust vents in each room are located so close to each other. Making this change may also minimize or eliminate the indoor air quality problem. A ventilation specialist should be consulted to increase the rate of air exchange.

A related recommendation is to develop material which can be used by school personnel to diagnose and alleviate future problems with indoor air pollution. This documentation can also be used as course material in awareness type educational experiences for the same personnel and be used as a guide to prevent similar problems in new buildings.

Case Study E

General Information

Demographic Data

School facility E, housing grades 6-8, is 33 years old and located in a residential neighborhood in the eastern midlands of South Carolina. The facility contains two buildings connected with a covered walkway. One of the buildings only contains classrooms which only open to the outdoors. The other also contains classrooms, administration offices, two teacher lounges, teacher workroom, gymnasium, cafeteria and kitchen, computer room, music room, storage room, boiler room, classroom laboratories, and washrooms.

The average number of occupants using the buildings, as reported by the principal, was 550 students, 30 teachers, and 7 staff. The visit was made March 19, 1987, from 9:00 to 11:30 AM. This facility is located in the same county as the one in Case Study F.

General Description of the Buildings

The smaller classroom building is one story in height, sits on a slab-on-grade foundation, and has a built-up finish flat roof. The other building is a combination one- and two-story structure. The one-story portion, housing the gymnasium, sits on a slab-on-grade foundation. The two-story portion has a basement below part of it and is supported by a combination of structural steel framing on column footings and concrete block bearing walls supported by wall footings. The exterior walls of both buildings are constructed of concrete block, covered with a brick veneer. There are metal frame windows and doors. There is no garage attached to either building.

The interior floors at all levels of both buildings are concrete. They are covered with floor tile in all areas except the basement storage, boiler room, and gymnasium. In the latter case, the concrete is covered with a wood floor. The ceilings are 12" x 12" acoustical tiles. The interior walls are built out of concrete block which have been painted.

The buildings are heated by a hot water distribution system. The gas-fired boiler and related controls are located in the boiler room. The boiler has its own ventilation to the outdoors at the roof level. The heating system is 33 years old. The heat is controlled for the entire facility from one thermostat located in the teachers' workroom. The buildings are not air conditioned with the exception of the teachers' lounge on the first level and the cafeteria. In the first case there is a window air conditioning unit which is about six years old. In the other case there is a separate central air conditioning unit that cools the entire space. The age of the central unit is about five years old.

The kitchen houses refrigeration, cooking, and food preparation equipment. The gas stove has its own ventilator which exhausts the air to the outdoors at the roof level. There is no other special mechanical ventilation in the buildings.

The fresh water is obtained from the city. Hot water is obtained from a gas-fired heater located in the boiler room. It has its own ventilation which exhausts to the roof level. The waste water is disposed into the city sewer system. The kitchen and washrooms contain conventional types of plumbing fixtures. There are also sinks in some of the classrooms. There are drinking fountains in the hallways and a sump pump in the boiler room.

Most of the lighting is fluorescent. The balance is incandescent. There are liquid-process copying machines in the workroom. The teachers' lounge on the first level contains a microwave oven, coke machine, and refrigerator. Many of the classrooms and the work room had portable floor fans in them. All the furniture is constructed of wood, plastic, and/or metal.

Health Information Form Data

The score on the HIF was 17 which placed this facility in the group having a high potential of problems with indoor air pollution. A summary of the responses from the form indicated the following:

1. There are "smoke stack" industries within one mile of the facility.

2. Relative to interior materials, equipment, and activities that might cause indoor air pollution, smoking is allowed (but only in the second floor teachers' lounge), natural gas space heaters and stoves exist in the large building, there does not exist a formal documented maintenance program, and the facility maintenance is poor.

3. In terms of the reported sensory information, the interior environment is hot, humid, and stuffy. The air quality is stale and the overall environment is rated as below acceptable.

4. Five of the 28 possible health-related symptoms were reported by the buildings' occupants.

5. Absences were greatest due to colds during January, 1986.

Results of Building Inspection

The following is a summary of the results of the inspection of the exterior and interior of both buildings. Relative to the interior of the larger building the following was inspected: both teacher lounges, workroom, boiler room, storage room, cafeteria, computer room (located on the basement level) and two classrooms (one on each level). In addition, two classrooms were inspected in the smaller building. The Comprehensive Building Survey and Room Survey Forms were used in the inspection process.

Building Exterior

The exterior grounds and finish materials were in fair condition. The walls, windows and doors needed cleaning. The smoke stacks from paper mills could be seen from the site of the facility. The quality of the air was average. The roof vents on the smaller buildings appeared to be in good condition as did the air exchange units on the roof of the larger building.

Building Interior

The condition of the floors, walls, and ceilings in all the rooms inspected were good to fair. There was some water damage on the ceilings of the cafeteria and teachers' lounge on the second floor which was due to a failure of the built-up roof finish. Water stains were also found on the ceiling of the workroom which is on the first floor. This was due either to spillage of water on the floor above which came through onto the ceiling or the failure of flashings on the exterior wall allowing water to enter the building at the ceiling level and getting into the tiles. There were no offensive odors. The air quality was generally stale and comfort level stuffy. There were odors of smoke in the second floor teachers' lounge.

Most of the mechanical, electrical, and plumbing equipment, fixtures, and auxiliary items such as vents and pipes were in fair condition. The only exception was the heating equipment and sump pump located in the boiler room. They were in poor condition. The intensity of the lighting in all the rooms inspected was good.

All toxic chemicals such as cleaning agents were contained in the storage room which opens to the outdoors and is accessible to anyone. Small amounts of cleaning agents were stored in the kitchen, workroom, and teachers' lounges. Duplication fluid for the copying machines was kept in the workroom which is also accessible to the buildings' occupants. Any chemicals used in the classroom laboratories are locked in cabinets. These classrooms are also kept locked.

There were no activities occurring in the building at the time of the visit which would cause indoor air pollution. The space containing the copying machines was well ventilated as are the storage and boiler rooms. All the equipment and furnishings known to be potential sources of indoor air contaminants were ventilated and maintained so as not to cause health-related problems. The remaining equipment and furnishings were not considered to be potential sources of indoor air quality problems.

Results from Interviews

The principal indicated that he has experienced some problems with the quality of air in the building. He feels this is due to the local smoke stack industries and the very poor level of housekeeping and maintenance in the facility. The principal expressed a high level of frustration with the small number of untrained custodial help that he is provided from the district system. He also indicated that the age of the heating system and lack of a facility-wide cooling system attributes to some of the problems. Some of the teachers and staff interviewed agreed with him. There is planned a complete overhaul of the heating system in 1987 along with the addition of a cooling system.

The principal noted that all housekeeping activities are performed after the classes are dismissed for the day. The only exceptions are for emergencies and routine tasks that must be done prior to and after lunch in the kitchen and cafeteria. Major maintenance activities such as waxing floors, painting, and insecticide treatment are done when classes are not in session such as on weekends or during school holidays. There have not been any building renovations or energy conservation projects performed within the past ten years.

Results of Environmental Measurements

The following environmental measurements were taken in some of the rooms inspected. The locations of the measurements were arbitrarily selected.

1. Eight temperatures were taken. They ranged from 75°F to 80°F, with a mean of 77°F.

2. Eight relative humidities were taken. They ranged from 30% to 40%, with a mean of 35%.

3. Four radon monitors were placed on the facility. The concentrations were 0.3 pC/1, 0.6 pC/1, 0.7 pC/1, and 1.0 pC/1, with a mean of 0.65 pC/1.

4. Two formaldehyde monitors were placed in the large building. The concentrations were 0.019 pm and 0.020 ppm, with a mean of 0.0195 ppm.

5. Five samples of air were taken to determine concentrations of carbon dioxide. The levels ranged from 600 ppm to 1000 ppm, with a mean of 720 ppm.

Findings

There does not appear to be any major problems with the quality of the indoor air. However, there are some minor problems. These are probably due to a combination of items. These include the existence of sources of outdoor air contaminants, a heating system which is not well maintained and in poor condition, and the lack of mechanical air exchange and cooling for the activity. This was verified during the inspection and from most of the responses on the HIF. The portable gas heaters noted as existing on the HIF were inoperable and thus not inspected. Also the HIF did not note that air conditioning existed in the large building. It cannot be verified if the reported five health-related symptoms were due to problems with air contaminants, contagious disease or from some other cause. The principal felt it was from a combination of the first two reasons. The other items on the HIF were verified during the inspection.

The concentrations of both the radon and formaldehyde were below their respective threshold levels. The range of temperatures and humidities were acceptable according to ASHRAE standards but the temperatures were on the high side and humidities on the dry side. This is resulting in the stuffy feeling in the building; along with the perception of stale air quality.

The air exchange rate, based on the mean concentration of carbon dioxide (720 ppm) was 27 cfm per person. This rate exceeds the minimum ASHRAE recommendations for both the existing (5 cfm per person) standard and proposed (15 cfm per person) standard for classrooms where smoking is not permitted. One of the classrooms has a concentration of 1000 cfm per person (15.5 cfm per person). This level is marginally acceptable but odors become more noticeable at and above this level.

The level of maintenance in and out of the building was poor. In discussions with the principal and teachers it was apparent that they were not aware of the problems with indoor air pollution. They were interested in learning about the subject and how it affects them and their students.

Recommendations

The temperature in the building should be lowered and humidity increased. Since the principal indicated that a major overhaul of the HVAC system is scheduled in the next year, the existing environmental problems may not exist for the installation of the system. When installing the system, the contractor should be required to balance the system so temperatures are below 75°F, humidities above 30% (preferably 40%) and a minimum air exchange rate of 15 cfm per person for classrooms, 20 cfm per person for laboratories and workshops, and 60 cfm per person for smoking areas are maintained.

Once the new HVAC system has been installed, it is recommended to perform another inspection and environmental evaluation similar to the one described in this case study. It is likely that the minor air quality problems will be minimized if not completely alleviated.

A further recommendation is to place a higher priority on the maintenance of the facility by assigning more trained personnel and supporting resources to the activity. Finally, it is recommended that the teachers and staff be provided with useful information on indoor air pollution and its health-related effects. They need to become aware of what causes it and how to prevent it.

Case Study F

General Information

Demographic Data

School facility F, housing grades K-3, is 30 years old and located in a rural environment in the eastern midlands of South Carolina. The facility contains three major buildings and one minor building connected with covered walkways, two small buildings containing one washroom, and one portable classroom. This study was limited to the three major and one minor building. Two of these contain classrooms some of which have washrooms. All the classrooms opened only to the outdoors. The third major building houses the administration offices, cafeteria, kitchen, storage room, boiler room, one classroom and washrooms. The minor building contained the teachers' lounge, workroom, computer room, and washroom.

The average number of occupants using the building, as reported by the principal, was 250 students, 15 teachers, and 6 staff. The visit was made on March 19, 1987, from 1:00 to 3:00 PM. The facility is in the same county as the one in Case Study E.

General Description of the Buildings

The buildings are all one-story in height, sit on slab-on-grade foundations, and have built-up finish flat roofs. The exterior walls are constructed of concrete block, covered with a brick veneer. There are metal frame windows and doors. There is no garage attached to the building.

The interior floors are concrete over which has been placed floor tile and in some locations carpet. The ceilings are fiberboard panels supported by steel straps and structural steel joists. The interior walls are constructed of concrete block which has been painted.

The buildings are heated by a hot water distribution system. The gas-fired boiler and related controls are located in the boiler room. The boiler has its own ventilation to the outdoors at the roof level. The heating system is one year old. Thermostats, used to control the heat, are located in all rooms except the storage room and janitor closet. The buildings are not air conditioned. The exception is the teachers' lounge which has a window air conditioning unit. This unit is five years old. There are no exhaust air vents in any of the rooms. Any air exchange is solely through openings in the walls.

The kitchen houses refrigeration, cooking, and food preparation equipment. The gas stove has its own ventilator which exhausts the air to the outdoors at the roof level. There is no other special mechanical ventilation in the buildings.

The fresh water is obtained from an on-site well. Hot water is obtained from a gas-fired heater located in the boiler room. It has its own exhaust vent to the outdoors at the roof level. The waste water is disposed to a septic system which is on the school property. The washrooms and kitchen contain the conventional types of plumbing fixtures.

There are sinks in some of the classrooms and a drinking fountain in the hallway of the building containing the administration offices. There is incandescent lighting in all the rooms.

The computer room contains not only computer equipment and supplies, but also a liquid-process copying machine. The teacher lounge contains a microwave oven. The furniture within the huge buildings is constructed of wood, plastic, and/or metal.

Health Information Form Data

The score on the HIF was 2 which placed this facility in the group having a low potential of problems withindoor air pollution. A summary of the responses from the form indicate the following:

1. The only possible external source of indoor contaminants is the well from which the fresh water is obtained.

2. Relative to interior materials, equipment, and activities that might cause indoor air pollution, the heating system is gas-fired.

3. In terms of reported sensory information, the interior environment is acceptable.

4. No health-related symptoms were reported by the occupants of the building.

5. Absences were greatest due to flu in January and February, 1986.

Results of Building Inspection

The following is a summary of the results of the inspection of the buildings' exterior, cafeteria, boiler room, computer room, teachers' lounge, and four classrooms (two in each classroom building). The Comprehensive Building Survey and Room Survey Forms were used in the inspection process.

Building Exterior

The exterior grounds and material finishes were in good to fair condition. Some of the building surfaces needed cleaning. There were no visible sources of outdoor air pollutants. The quality of air was excellent. The roof air handling unit and vents appeared to be in good condition. There was a considerable amount of rusting of the exposed structural steel supporting the walkways.

Building Interior

The condition of the floors, walls, and ceilings in all of the rooms inspected were good to fair. There was some moisture damage on the ceilings in some of the rooms due to the failure of the built-up roof finish. In addition, the floor in the boiler room was discolored adjacent to the floor drain. This was caused by water coming from the condensate line of the boiler and/or a backup of the floor drain line.

There were no offensive odors. The air quality was acceptable to stale. The general comfort of the buildings ranged from stuffy to acceptable.

The condition of the mechanical, plumbing, and electrical equipment, fixtures, and auxiliary items such as vents and pipes was fair to good. The intensity of lighting was fair.

All cleaning and other potentially harmful substances were kept in a storage room off the cafeteria. This room was kept locked. A small amount of duplication fluid was stored in the computer room which is constantly monitored by a teacher. There were no activities occurring in the buildings at the time of the visit which would cause indoor air pollution. The computer room was adequately ventilated for the operation of the copy machine. All of the equipment and furnishings known to be potential sources of indoor air contaminants were well ventilated and adequately maintained so as not to cause health-related problems. The remaining equipment and furnishings were considered to be potential sources of indoor air quality problems.

Results from Interviews

The principal stated that there had not been any continuous indoor air quality problems. One of the teachers indicated that there was very little fresh air coming into the classroom located in the building containing the cafeteria.

The principal noted that all housekeeping activities are performed after the classes end each day. The only exception is in cases of emergencies and routine tasks that must be done prior to and after lunch in the cafeteria and kitchen.

Major maintenance activities such as insecticide treatment, painting, and similar tasks are performed when classes are not in session such as on weekends or during school holidays. There have not been any building renovations or energy conservation projects performed within the last ten years.

Results of Environmental Measurements

The following environmental measurements were taken in some of the rooms inspected. The locations of the measurements were arbitrarily selected.

1. Five temperatures were taken. They ranged from 76°F to 81°F, with a mean of 77°F.

2. Five relative humidities were taken. They ranged from 34% to 43%, with a mean of 39%.

3. Two radon monitors were placed in the facility. The concentrations were 0.2 pC/l and 0.5 pC/l, with a mean of 0.35 pC/l.

4. Five samples of air were taken to determine the concentration of carbon dioxide. They ranged from 500 ppm to 1300 ppm, with a mean of 780 ppm.

Findings

There does not appear to be any overall problem with the quality of the indoor air. This was supported by the statements of the principal and teachers and the results of the inspection. The existence of a window air conditioning unit and gas stove was not indicated on the HIF. The other responses on the form were verified during the inspection.

Both concentrations of radon were below the threshold level. The range of temperatures were acceptable but generally on the high side according to ASHRAE recommendations. The relative humidities were also acceptable but on the dry side according to ASHRAE recommendations. The combination of high temperatures and low humidities was confirmed by the somewhat stuffy feeling in some of the rooms and slightly stale quality of the air.

The mean concentration of carbon dioxide (780 ppm) corresponds to an air exchange rate of 23 cfm per person. This rate exceeds the minimum ASHRAE recommendations for both the existing (5 cfm per person) and the proposed (15 cfm per person) standard for rooms where smoking is not allowed. However, two of the classrooms had concentrations of 1000 ppm and 1300 ppm, respectively, which corresponds to 15 cfm per person and 11 cfm per person air exchange rates. Both of these are acceptable relative to the present ASHRAE standard, but one is not under the proposed guideline. It is interesting to note that the room having the high concentration was the same one which the teacher complained about not having an adequate supply of fresh air. Furthermore, problems with objectionable odors can exist with such high concentrations (though there were no reports of odors during the inspection).

The level of maintenance appeared to be good. In discussions with the principal and teachers it was apparent that they were not aware of the problems with indoor air pollution. They were interested in learning about the subject and how it affects them and their students.

Recommendations

The temperatures within the buildings should be lowered. Since there are no cooling systems (except for the teachers' lounge), this can be accomplished by opening windows and/or doors. Since the inspection was done in March and the hottest months of the school year had not yet arrived, it is suspected that temperature conditions become even worse during May and June. In this case the school district should consider installing a cooling system such as window air conditioning units. This would not only solve the high temperature problem but also prevent problems of dirt and insects getting into the rooms when windows and doors are left open.

Another recommendation is to increase the humidity levels. This can be accomplished by installing humidifiers in the rooms. If this is done, however, they must be maintained so as not to be the cause of indoor air pollution. When altering the temperature, the level of the relative humidity is changed. Therefore, it is recommended that before implementing any major changes to the indoor environment, a ventilation specialist be consulted to evaluate the present conditions and suggest changes.

Furthermore, the air exchange rate should be increased to a minimum of 15 cfm per person for nonsmoking areas and 60 cfm per person in areas where smoking is allowed. This should be done in consultation with the ventilation specialist. Following the above stated temperature, humidity, and air exchange recommendations will result in a more comfortable environment having better air quality.

Finally, it is recommended that the teachers and staff be provided with usable information on indoor air pollution and its effects. They need to become aware of its sources and how to prevent and alleviate it.

Case Study G

General Information

Demographic Data

School building G, housing grades K-5, is 5 years old and located in a rural environment in the piedmont of South Carolina. The building contains classrooms, cafeteria, kitchen, music room, atrium, art room, media center, administration offices, teachers' lounge, janitor closets, storage room, boiler room, and washrooms.

The average number of occupants of the building, as reported by the principal, was 830 students, 49 teachers, and 18 staff. The visit took place on March 17, 1987, from 9:00 AM to 11:30 AM. The building is in the same county as those in Case Studies A, C, I, and J.

General Description of the Building

The building is one-story in height, sits on a slab-on-grade foundation, and has sloped roofs finished with fiberglass shingles. The exterior walls are constructed of concrete block, covered with a brick veneer. There are metal frame windows and doors. There is no garage attached to the building.

The interior floors are concrete over which has been placed vinyl floor tile and in some locations carpet. The ceilings are drop-type which integrate acoustical panels with the lighting and supply and exhaust air vents. The interior walls are constructed of concrete block which have been painted. Most classrooms open up to both the outdoors and interior hallways.

The building is heated and cooled by a water distribution system. During the winter months, the water is heated by an electric-powered boiler located in the boiler room. During warm weather the water is chilled by two electric-powered cooling units located outside the building adjacent to the boiler room. The entire HVAC system is the same age as the building. The fresh air intake and exhaust vents are not located in close proximity of each other. The temperature is controlled by thermostats which are located in every other classroom, large spaces such as the media center and cafeteria, and the administration offices.

The kitchen contains refrigeration, cooking, and food preparation equipment. The electric stoves have their own ventilators which exhaust the air to the outdoors at the roof level. There is no other special mechanical ventilation in the building.

The fresh water is obtained from the city. Hot water is obtained from an electric-powered heater located in the boiler room. The waste water is disposed into the county sewer system. The kitchen and washrooms contain conventional types of plumbing fixtures. There are also sinks in some of the classrooms, two in the janitor's closets, teachers' lounge and in the teachers' work areas, which are in enlarged corridors immediately outside a series of classrooms. There are drinking fountains in the hallways.

A smoke detector system is located throughout the building. All lighting is fluorescent. There are liquid-process copying machines located in the teachers' work areas. The teachers' lounge contains a refrigerator and microwave oven. All the furniture is constructed of wood, plastic, and/or metal.

Health Information Form Data

The score on the HIF was 2 which placed this facility in the group having a low potential of problems with indoor air pollution. A summary of the responses from the form indicated the following:

1. There are no visible exterior sources of outdoor air pollutants.

2. Relative to interior materials, equipment, and activities that might cause indoor air pollution, smoking was allowed (but only in a small room off the boiler room) and the building contained central air conditioning.

3. In terms of the reported sensory information, the interior environment is acceptable.

4. No health-related symptoms were reported by the building's occupants.

5. Absences were greatest due to a flu epidemic in February, 1986.

Results of Building Inspection

The following is a summary of the results of the inspection of the building exterior, media room, art room, music room, teachers' lounge, cafeteria, boiler room, and two classrooms. The Comprehensive Building Survey and Room Survey Forms were used in the inspection process.

Building Exterior

The exterior grounds and material finishes were in good condition. There were no visible sources of outdoor air pollution. The quality of air was excellent. The roof ventilator and vents appeared to be in good condition, as did the outside cooling units.

Building Interior

The condition of floors, walls and ceilings in all the rooms were in good condition. No moisture problems were found except in the boiler room. The floor was stained from a prior leak from the boiler.

There were no offensive odors. The air quality was good except in the teachers' lounge where it was stale. The general comfort throughout the building was acceptable to stuffy.

All mechanical, electrical, and plumbing equipment, fixtures, and auxiliary items such as vents and pipes were in good condition. The intensity of the lighting was good in all rooms inspected.

All toxic chemicals such as cleaning agents were contained in the storage room which is inaccessible to students and opens only to the outdoors. Small amounts of cleaning agents were kept in the janitor closets which are also kept locked and were well ventilated. Duplication fluid for the copy machines was stored in cabinets adjacent to them. They are kept locked.

There were no activities occurring in the building at the time of the visit which would cause indoor air pollution. The space containing the copying machines is well ventilated as are the stoves in the kitchen. All equipment and furnishings known to be potential sources of indoor air contaminants were well ventilated and adequately maintained so as not to cause health-related problems. The remaining equipment and furnishings were not considered to be potential sources of indoor air quality problems.

Results from Interviews

The principal indicated that problems did not presently exist with the quality of the indoor air. It was noted, however, that at times there were noticeable temperature differences among the rooms. The principal noted that the teachers were encouraged to open the doors to the outside when the temperature of their classroom reached an uncomfortable level. This was substantiated by the teachers interviewed.

All housekeeping tasks are performed when classes are not in session such as when the children are at lunch or after classes are dismissed for the day. Toxic cleaning agents are only used in housekeeping tasks that are done at the end of the day. Major maintenance activities such as insecticide treatment, painting, and waxing of floors are performed on weekends or during school holidays. There have not been any building renovations or energy conservation projects performed since the building was constructed.

Results of Environmental Measures

The following environmental measures were taken in some of the rooms. The locations of the measurements were arbitrarily selected.

1. Six temperatures were taken. They ranged from 78°F to 79°F, with a mean of 78°F.

2. Six relative humidities were taken. They ranged from 26% to 29%, with a mean of 28%.

3. Three radon monitors were placed in the building. The concentrations were 2.3 pC/1, 3.3 pC/1, and 4.8 pC/1, with a mean of 3.5 pC/1.

4. Two formaldehyde monitors were placed in the building. The concentrations were 0.034 ppm and 0.065 ppm, with a mean of 0.50 ppm.

5. Five air samples were taken to determine the concentration of carbon dioxide. They ranged from 800 ppm to 1100 ppm, with a mean of 960 ppm.

Findings

There do not appear to be any problems with the quality of the indoor air. This is supported by the statements of the principal and teachers, the results of the inspection, and the responses from the HIF, which were verified during the inspection.

The concentrations of the radon and formaldehyde were below levels that would cause health-related problems. The range of temperatures are acceptable according to ASHRAE recommendations, but on the high side. All the relative humidities were below the acceptable level noted by ASHRAE. This, in conjunction with the high temperatures, created the stuffy feeling and stale air quality in some of the rooms. There did not appear to be differences in the temperatures among the various rooms as reported by the principal.

The air exchange rate, based on the mean concentration of carbon dioxide (980 ppm) is 17 cfm per person. This is above both the existing minimum (5 cfm per person) and proposed (15 cfm per person) minimum ASHRAE standards for nonsmoking areas. Three of the carbon dioxide measurements are at or over 1000 ppm. Objectionable odors are more noticeable above 1000 ppm (though none were reported or detected during the inspection). In addition, the proposed minimum ASHRAE air exchange standards converted to concentration of carbon dioxide (1050 ppm) would indicate that there is insufficient air exchange in those rooms where the level of carbon dioxide exceeds 1000 ppm.

The level of maintenance appears to be good. In discussions with the principal and teachers, it was apparent that they were not aware of the problems with indoor air pollution. They were interested in learning about the subject.

Recommendations

The humidity level in the building should be increased to 30% or more. This can be accomplished by introducing moisture into the air such as through humidifiers. If used, they must be closely maintained so as not to create indoor air quality problems.

In addition, the temperature should be reduced to below 75°F. Since altering the temperature will also alter the relative humidity, a ventilation specialist should be consulted to perform the necessary changes. A further related recommendation is not to open the exterior doors when the central heating and cooling system is operating. This will cause the system to become unbalanced and create uneven heating and cooling.

The minimum air exchange rate should be at least 5 cfm per person in nonsmoking areas, and 60 cfm per person in areas in which smoking is allowed. This should be accomplished in consultation with the ventilation specialist. By making the recommended changes to the temperature, humidity, and air exchange rate a more comfortable indoor environment will result.

Finally, it is recommended that the teachers and staff be provided with useful information on indoor air pollution and its health-related effects. They need to become aware of what causes it and how to prevent it.

Case Study H

General Information

Demographic Data

School building H, housing grades K-6, is 8 years old and located in a residential neighborhood in the coastal plain of South Carolina within 50 miles of the Atlantic Ocean. The building contains classrooms, administration offices, teacher lounge and workroom, media center, mechanical room, storage room, janitor closets and washrooms. This is one of a series of buildings in the elementary school complex. The others consist of the cafeteria and kitchen and twelve portable classrooms. These were not part of this study.

The average number of occupants in the building, as reported by the principal, was 900 students, 60 teachers, and 15 staff. The visit took place on March 18, 1987, from 1:00 to 3:30 PM. This school is in the same city as that in Case Study D.

General Description of the Building

The building is one-story in height, sits on a slab-on-grade foundation, and has a built-up finish flat roof. The exterior wall is constructed of concrete block and covered with a brick veneer. There are metal frame windows and doors. There is no garage attached to the building.

The interior floors are concrete over which has been placed vinyl floor tile and in some locations carpet. The ceilings are drop-type with acoustical panels integrating the lights and fresh air and exhaust vents. The interior walls are constructed of concrete block which has been painted and drywall (also painted) over steel studs.

The building is heated and cooled by electric-powered heat pumps which are located on the roof. The system is eight years old. The temperature is controlled by thermostats. There is one thermostat for each cluster of five rooms. The fresh air comes in from the roof level and stale air exhausted at the same level but not in the same proximity. There is no special mechanical ventilation for any of the rooms in the building.

Fresh water is obtained from the city. Hot water is obtained from an electric-powered heater located in the mechanical room. Waste water is disposed into a city sewer system. The washrooms contain the typical kinds of plumbing fixtures and there are sinks in some of the classrooms, the teachers' lounge, and janitor closets. There are drinking fountains in the hallways. All rooms have fluorescent lighting.

The teachers' lounge contains a microwave oven, refrigerator, soda, and snack machine. The workroom contains four liquid-process copying machines. The office and

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classroom furniture is constructed of wood, plastic, and/or metal.

Health Information Form Data

The score on the HIF was 2 which placed this building in the group having a low potential of problems with indoor air pollution. A summary of the responses from the form indicated the following:

1. There are no visible exterior sources of outdoor air pollutants.

2. Relative to interior materials, equipment, and activities that might cause indoor air pollution, smoking was allowed (but only in the teachers' lounge before and after school) and central air conditioning exists.

3. In terms of the reported sensory information, the interior environment is acceptable.

4. No health-related symptoms were reported by the occupants of the building.

5. Absences were greatest due to colds in December, 1985, and January and February, 1986.

Results of Building Inspection

The following is a summary of the results of the inspection of the building's exterior, teacher's lounge, workroom, mechanical room, media room, and two randomly selected classrooms. The Comprehensive Building Survey and Room Survey Forms were used in the inspection process.

Building Exterior

The exterior grounds and material finishes were in good condition. There were no visible sources of outdoor air pollutants. The quality of air was good. The rooftop vents and heat pumps appeared to be in good condition.

Building Interior

The condition of the floors, walls, and ceilings in the rooms inspected was good. The ceiling tiles in the workroom were discolored in places indicating moisture damage. This was due to either a leaky roof or a break in the condensate drain line from the heat pump which sits above the ceiling.

There were no offensive odors. The air quality was generally acceptable. The comfort within the building was stuffy to acceptable.

The condition of the mechanical, plumbing, and electrical equipment, fixtures, and auxiliary items such as vents and pipes was good. The intensity of the lighting was good in all rooms.

Harmful substances such as cleaning fluids were contained in a storage room which is only accessible from the outdoors. Small amounts of the same substances were kept in the janitor closets. All these spaces were well ventilated and inaccessible to the students. Duplication fluid is stored in the workroom which was also inaccessible to the students, and well ventilated.

There were no activities occurring in the building at the time of the visit that would cause indoor air pollution. All equipment and furnishings known to be potential sources of indoor air contaminants were well ventilated and adequately maintained so as not to cause health-related problems. The remaining equipment and furnishings were not considered to be potential sources of indoor air quality problems.

Results from Interviews

The principal stated that there were no continuous problems with the quality of the indoor air. Two of the teachers and one of the secretaries indicated that some of the rooms in the building become very stuffy at times. This occurs near the end of the school day or when there was no air coming out of the ceiling vents.

The principal noted that all housekeeping activities are performed after the classes end for the day except in emergencies. Major maintenance tasks such as painting, waxing floors and insecticide treatment are done when classes are not in session, such as on weekends or during school holidays. No building renovations or energy conservation projects have been performed since the construction of the facility.

Results of Environmental Measurements

The following environmental measurements were taken in some of the rooms inspected. The locations of the measurements were arbitrarily selected.

1. Five temperatures were taken. They ranged from 72°F to 78°F, with a mean of 77°F.

2. Five relative humidities were taken. They ranged from 26% to 30%, with a mean of 27%.

3. Three radon monitors were placed in the building. The concentrations were 0.8 pC/1, 0.5 pC/1, and 0.6 pC/1, with a mean of 0.63 pC/1.

4. Five air samples were taken to determine the concentrations of carbon dioxide. For four of them, the concentrations ranged from 600 ppm to 1000 ppm, with a mean of 825 ppm. The fifth sample had a concentration of 4000 ppm.

Findings

There does not appear to be any overall problem with the quality of the indoor air. This was supported by the statements of the principal and teachers, the results of the inspection, and the responses from the HIF, which were verified during the inspection.

The concentrations of the radon were below the threshold level. The temperatures were acceptable according to ASHRAE recommendations, but on the high side. All the relative humidities were below that recommended by ASHRAE (30%). This, in conjunction with the high temperatures, was creating the stuffy feeling in some parts of the building as reported by some of the occupants.

The air exchange rate, based on the mean concentration of carbon dioxide (825 ppm) is 21 cfm per person. This is above the minimum of 5 cfm per person specified for nonsmoking areas by the current ASHRAE standards. It also would meet the minimum requirements set forth in the proposed ASHRAE standards (15 cfm per person in nonsmoking areas). Two of the four concentrations were 1000 ppm. At and above this level objectionable odors become a problem, though none were reported or noticed during the inspection. In addition, at the 1000 ppm level, the air exchange rate of 15.5 cfm per person is coming close to not meeting the proposed ASHRAE standard.

The fifth concentration of 4000 ppm is unusually high. It corresponds to a 3 cfm per person air exchange rate which is below the minimum current ASHRAE standard. Discussions with the principal uncovered the fact that the air handling unit serving this and other surrounding rooms is shut off at least an hour prior to the end of the class day as an energy conservation measure. The carbon dioxide measurement was taken within that hour. The level of carbon dioxide had built up to the concentration noted from the test.

The level of maintenance appeared to be fair to good. In discussions with the principal, teachers, and staff, it was apparent that they were not aware of the problems with indoor air pollution. They were interested in learning more about the subject.

Recommendations

The humidity level in the building should be increased. This can be accomplished by installing humidifiers. If used, they must be closely maintained so they do not become a source of indoor air contaminants.

In addition, the temperatures should be reduced to below 75°F. Since altering the temperature will also change the relative humidity, a ventilation specialist should be consulted to perform the necessary changes. A further recommendation is to reset the timers on the various rooftop air handling units (heat pumps) so they are activated at least one hour prior to the start of classes and are not turned off until classes have been dismissed for at least 30 minutes. There should be a minimum air exchange rate of 15 cfm per person for nonsmoking areas and 60 cfm per person for areas in which smoking is allowed. This should be attained in consultation with the ventilation specialist. Taking these steps will improve the quality of the air and result in a more comfortable environment.

Finally, it is recommended that the teachers and staff be provided with usable information on indoor air pollution and its health-related effects. They need to become aware of what causes it and how to prevent it.

Case Study I

General Description

Demographic Data

School Building I, housing grades K-5, is 47 years old and located in a residential neighborhood in the upper piedmont of South Carolina. The building is one of four making up the elementary school site. It houses classrooms, auditorium, library, media room, boiler room, teacher workroom and lounge, janitor closets and washrooms.

The average number of occupants in the building, as reported by the principal, was 250 students, 11 teachers, and two staff. The visit took place on March 16, 1987, from 9:00 to 11:30 AM. This building is in the same county as those in Case Studies A, C, G, and J.

General Description of the Building

The building is two stories in height and has a basement. It is a combination steel and wood frame structure with column footings as part of the foundation. The other part are wall footings supporting the masonry exterior walls of clay tile units faced with brick. The roof is flat with a built-up finish. There are wood frame windows and doors. There is no garage attached to the building.

The basement floor is concrete. Part of it is covered with floor tile. The floors of the upper levels are constructed of wood some of which have been covered with carpet and tile. The ceilings are all wood covered with painted fiberboard panels. The interior walls are constructed of wood covered with wood lath and plaster. The plaster has been painted. The interior side of the exterior walls have also been plastered and painted. Rooms have a twelve foot floor to ceiling height. This height is 20 or more feet in the auditorium.

The building is heated by a gas-fired forced air system. The heating equipment is located in the boiler room which is in the basement. The gas furnace has its own ventilation to exhaust contaminated air to the outdoors through the exterior wall. Every room has fresh and return air vents. They are both on the interior walls near the ceiling. They are both in the interior walls near the ceiling. The temperature is controlled by thermostats which are located in various places in the building, but not in every room. Most of the rooms have window air conditioning units. There is no special mechanical ventilation in the building.

The fresh water is obtained from the city. Hot water is obtained from a gas-fired heater located in the boiler room. It has its own ventilation which exhausts to the outdoors through an exterior wall. The waste water is disposed into the city sewer system. The washrooms contain conventional types of plumbing fixtures. The teachers' workroom and lounge contains a washroom, but none of the classrooms do. A few of the classrooms contain sinks.

The rooms have fluorescent and incandescent lighting. There is a liquid-process copying machine in the teachers' workroom and lounge. All the furniture is constructed of wood, plastic, and/or metal.

Health Information Form Data

The score on the HIF was 2 which placed this building in the group having a low potential of problems with indoor air pollution. A summary of the responses from the form indicated the following:

1. There are no visible exterior sources of outdoor pollutants.

2. Relative to interior materials, equipment, and activities that might cause indoor air pollution, the building contained a gas-fired furnace and room air conditioning units.

3. In terms of the reported sensory information, the interior environment is acceptable.

4. No health-related symptoms were reported by the buildings' occupants.

5. Absences were greatest due to flu in January and February, 1986.

Results of Building Inspection

The following is a summary of the results of the inspection of the building exterior, boiler room, media room, library, auditorium, teachers' lounge and workroom, and two classrooms (one on each floor, not including the basement). The Comprehensive Building Survey and Room Survey Forms were used in the inspection process.

Building Exterior

The exterior grounds and material finishes were in fair to good condition. Some of the exterior brick had some localized moisture damage. There were no visible sources of outdoor air pollution. The quality of the air was generally good. Natural gas odors could be detected immediately outside the boiler room. All the mechanical vents were in good condition.

Building Interior

The condition of the floors, walls, and ceilings in all the rooms inspected were in good condition. There was some standing water in the boiler room. It was from a past leaky fresh water pipe. This water had caused some discoloration of the concrete but no major damage.

There were no offensive odors. The air quality was acceptable to stale. The general comfort in the building was stuffy to acceptable. Many of the classrooms had their windows opened.

All mechanical, electrical, and plumbing equipment, fixtures, and auxiliary items such as pipes and vents were in fair to good condition. The exception to this were some of the window air conditioning units which were inoperable. The intensity of lighting was good to fair.

All toxic chemicals such as cleaning agents were stored in a small room off the boiler room. This area only opens up to the outdoors and is not accessible to the students. Duplication fluid for the copying machines was stored in the teachers' workroom and lounge. This space was fairly well ventilated and inaccessible to the students.

There were no activities occurring in the building at the time of the visit which would cause indoor air pollution. All of the equipment and furnishings known to be potential sources of indoor air contaminants were well ventilated and maintained so as not to cause health-related problems. The remaining equipment and furnishings were not considered to be potential sources of indoor air quality problems.

Results from Interviews

The principal indicated that there are no problems with the quality of the indoor air. Previous to the visit, a sewer line had backed up into one of the classrooms in the basement. It created very objectionable odors. The students were moved to another area of the building while the room was being cleaned up.

The teachers in many of the rooms indicated that the building tends to get very warm, which forces them to open the windows to get fresh, cooler air into their rooms. This is especially the case on the second floor. The principal noted that in order to get heat into the other buildings in the facility, the heat must be turned up, creating warmer temperatures in the main building. The teachers stated that at times, opening the windows creates drafty conditions in the classrooms. They also indicated that many of the room air conditioning units were not functioning properly.

All housekeeping activities are performed after classes are dismissed for the day except in emergencies. Major maintenance tasks such as painting, insecticide treatment, and waxing floors is done on weekends or during school holidays. There have not been any building renovations or energy conservation projects performed in the building within the last five years.

Results of Environmental Measurements

The following environmental measurements were taken in some of the rooms inspected. The locations of the measurements were arbitrarily selected.

1. Six temperatures were taken. They ranged from 76°F to 78°F, with a mean of 77°F.

2. Six relative humidities were taken. They ranged from 26% to 30%, with a mean of 28%.

3. Three radon monitors were placed in the building. The concentrations were 0.8 pC/1, 1.8 pC/1, and 2.3 pC/1, with a mean of 1.6 pC/1.

4. Five air samples were taken to determine the concentration of carbon dioxide. The levels ranged from 500 ppm to 1000 ppm, with a mean of 660 ppm.

Findings

There does not appear to be any problems with the quality of the indoor air. This was supported by the statements of the principal and teachers, the results of the inspection, and the responses from the HIF which were verified during the inspection.

The concentration of radon was below the threshold level. The range of temperatures were acceptable according to ASHRAE standards but on the high side. The relative humidities were all slightly below the minimum (30%) specified by ASHRAE. The combination of low humidity and high temperature was resulting in the stuffy feeling in the building.

The air exchange rate, based on the mean concentration of carbon dioxide (660 ppm) is 31 cfm per person. This is above the minimum specified in both the existing (5 cfm per person) and proposed (15 cfm per person) ASHRAE standards for rooms in which smoking is not allowed. The highest carbon dioxide concentration of 1000 ppm is also acceptable under the current and proposed standards. However, objectionable odors become more noticeable at carbon dioxide levels at and above 1000 ppm. In addition, the room having the highest level had its windows closed while the others were opened. This raises the possibility of problems with low rates of air exchange when the windows are closed such as during the winter months.

The level of maintenance appeared to be good. In discussions with the principal and teachers it was apparent that they were not aware of the problems with indoor air pollution. They were interested in learning more about it.

Recommendations

The temperature in the various rooms should be lowered to 75°F. In addition, the relative humidities should be raised to above 30%. The latter can be accomplished through the use of humidifiers. If they are used in the building they must be maintained in accordance with the manufacturer's instructions. A lack of care will lead to potential indoor air quality problems. Since altering the temperature will also change the relative humidity, it is recommended that a ventilation specialist be consulted to make any changes.

This is especially important for this case since there is very little opportunity to control the rate of air exchange. Opening the windows is ineffective in terms of the overall operation (not to mention the efficiency) of the central heating system. The specialist will take all these factors into consideration when analyzing the situation.

Finally it is recommended that the teachers and staff be provided with usable information on indoor air pollution and its health-related effects. They need to become aware of what causes it and how to prevent it.

Case Study J

General Information

Demographic Data

School building J, housing grades K-5, is six years old and located in a residential neighborhood in the upper piedmont of South Carolina. The building contains classrooms, administration offices, cafeteria, kitchen, media center, art room, teachers' lounge and workroom, mechanical room, janitor closets, storage room, and washrooms.

The average number of occupants of the building, as reported by the principal, was 755 students, 42 teachers, and 17 staff. The visit took place on March 16, 1987, from 1:00 to 3:30 PM. This building is in the same county as those in Case Studies A, C, G, and I.

General Description of the Building

The major portion of the building is two stories in height. A small section of it is single-story. It is structurally supported by a combination of steel frame on column footings, concrete block walls supported on wall footings and slab-on-grade. The roof is flat with a built-up finish. The exterior walls are constructed of concrete block, covered with brick veneer. There are metal frame windows and doors. There is no garage attached to the building.

The interior floors are concrete over which has been placed vinyl floor tile and in some locations carpet. The ceilings are drop-type which integrates acoustical panels with the lighting and supply and exhaust air vents. The interior walls are constructed of concrete block which has been painted.

The building is heated and cooled by a water distribution system. During the cold months, the water is heated by an electric-powered boiler located in the mechanical room. During warm weather, the water is chilled by an electric-powered cooling unit located outside the building adjacent to the mechanical room. The entire HVAC system is the same age as the building. The fresh air intake and exhaust vents are not located in close proximity to each other. The temperature in the building is controlled by thermostats in every room except the storage room, mechanical room, and janitor closets.

The kitchen contains refrigeration, cooking, and food preparation equipment. The electric stoves have their own ventilators which exhaust air to the outdoors at the roof level. There is no other special mechanical ventilation in the building.

The fresh water is obtained from the city. Hot water is obtained from an electric-powered heater located in the mechanical room. The waste water is disposed into the city sewer system. The kitchen and washrooms contain conventional types of plumbing fixtures. There are also sinks in some of the classrooms, one of the janitor's closets, teachers' lounge, and workroom. There are drinking fountains in the hallways.

A smoke detector system is located throughout the building. All rooms have fluorescent lighting. There are liquid-process copying machines in the teachers' workroom. The teachers' lounge contains a refrigerator, toaster oven, microwave oven, and soda machine. All the furniture is constructed of wood, plastic, and/or metal.

Health Information Form Data

The score on the HIF was 1 which placed this building in the group having a low potential of problems with indoor air pollution. A summary of the responses from the form indicated the following:

1. There are no visible exterior sources of outdoor air pollutants.

2. Relative to interior materials, equipment, and activities that might cause indoor air pollution, the building contained central air conditioning.

3. In terms of the reported sensory information, the interior environment is acceptable.

4. No health-related symptoms were reported by the building's occupants.

5. Absences were greatest due to flu and colds during January and February, 1986.

Results of Building Inspection

The following is a summary of the results of the inspection of the buildings' exterior, media room, art room, teachers' lounge and workroom, cafeteria and kitchen, mechanical room and two randomly selected classrooms (one on each level). The Comprehensive Building Survey and Room Survey Forms were used in the inspection process.

Building Exterior

The exterior grounds and material finishes were in good condition. There were no visible sources of outdoor air pollution. The quality of the air was excellent. The rooftop air handling unit and vents appeared to be in good condition as did the outdoor cooling unit.

A large trash container was located adjacent to the cooling unit. This could become a potential health problem, especially if organic matter is placed in the salvage bin. Germs, originating from the decomposition of the organic matter, could get into the cooling unit, causing bacterialogical contamination of the chilled water which, in turn, may affect the health of the building's occupants.

Building Interior

The condition of the floors, walls, and ceilings in all of the rooms inspected were in good condition. No moisture problems were observed.

There were no offensive odors. The air quality was acceptable to stale. The general comfort throughout the building ranged from acceptable to stuffy.

All mechanical, electrical, and plumbing equipment, fixtures, and auxiliary items such as vents and pipes were in good condition. The intensity of the lighting was good in all the rooms inspected.

All toxic chemicals such as cleaning agents were contained in the storage room which opens only to the outdoors and is inaccessible to the students. The storage room was well ventilated. Small amounts of cleaning agents are kept in the janitor closets. These rooms were kept locked and were well ventilated. Duplication fluid for the copy machines was stored in the teachers' workroom which was also well ventilated.

There were no activities occurring in the building at the time of the visit which would cause indoor air pollution. All equipment and furnishings known to be potential sources of indoor air contaminants were well ventilated and adequately maintained so as not to cause health-related problems. The remaining equipment and furnishings were not considered to be a potential source of indoor air quality problems.

Results from Interviews

The principal indicated that no problems exist with the quality of the indoor air. All housekeeping activities are performed after classes have been dismissed for the day. The exceptions are for emergencies and after lunch in the cafeteria and kitchen. Major maintenance tasks such as painting, waxing floors, and insecticide treatment are performed on weekends or during school holidays. There have not been any building renovations or energy conservation projects performed since the building was constructed.

Results of Environmental Measurements

The following environmental measurements were taken in some of the rooms inspected. The locations of the measurements were randomly selected.

1. Six temperatures were taken. They ranged from 73°F to 76°F in five locations, with a mean of 75°F. The sixth measurement was taken in the teachers' lounge and it was 82°F.

2. Six relative humidities were taken. They ranged from 30% to 36%, with a mean of 34%.

3. Three radon monitors were placed in the building. The concentrations were 0.80 pC/1, 1.2 pC/1, and 4.1 pC/1, with a mean of 2.0 pC/1.

4. Five air samples were taken to determine the concentration of carbon dioxide. The levels ranged from 1200 ppm to 220 ppm, with a mean of 1540 ppm.

Findings

There do not appear to be any problems with the quality of the indoor air. This is supported by the statements of the principal and teachers, the results of the inspection, and the responses from the HIF, which were verified during this inspection.

The concentration of radon was below the threshold level. The range of temperatures in the rooms surveyed, with the exception of the teachers' lounge, were acceptable according to ASHRAE standards. All the relative humidities were also in the acceptable ASHRAE range but on the low or dry side. This is why there was a stuffy feeling in some of the rooms.

The air exchange rate, based on the mean concentration of carbon dioxide (1540 ppm) is about 9 cfm per person. This is above the minimum of 5 cfm per person for nonsmoking areas specified by the current ASHRAE standards, but not acceptable under the proposed minimum limit of 15 cfm per person in nonsmoking areas. All of the carbon dioxide levels measured were above 1200 ppm. This will result in a higher sensitivity to objectionable odors by the building's occupants (though none were detected or reported during the inspection). In addition, a concentration of 1200 ppm corresponds to an air exchange rate of 12 cfm per person which would not meet the proposed ASHRAE standards.

The level of maintenance appeared to be good. In discussions with the principal and teachers it was apparent that they were not aware of the problems with indoor air pollution. They were interested in learning more about it.

Recommendations

The temperature in the teachers' lounge should be lowered. A ventilation specialist should be consulted to perform this task. In addition, consideration should be given to increase the relative humidities. This could be done in conjunction with altering the temperature not only in the teachers' lounge but also the other rooms.

The air exchange rate should be increased to 15 cfm per person in nonsmoking areas and 60 cfm per person in areas where smoking is allowed. This, along with any adjustments in temperature and humidity, will improve the quality of the air and comfort level within the building. The appropriate school personnel should work with the ventilation specialists in accomplishing this task. Finally, it is recommended that the teachers and staff be provided with useful information on indoor air pollution and its health-related effects. They need to become aware of what causes it and how to prevent it.

Case Study Analysis

Table 4.11 summarizes the major findings of all ten case studies. Table 4.12 presents a summary of the scores to the various parts of the HIF for the ten case studies. The information has been grouped by the potential of problems (based on the total form score) with indoor air pollution. Of the five selected schools scoring the highest on the HIF,

Table 4.11

Summary of Major Findings From Case Studies

	A	B	C	D	E
Age of facility in years	30	9	26	32	33
Case study facilities in immediate area	C,G,I,J	--	A,G,I,J	H	F
How heated	Oil-fired boiler	Electric heat pump	Gas boiler	Electric heat pump	Gas boiler
How cooled	None (a few window units)	Electric heat pump	Window Units	Electric heat pump	None (only one room unit)
Location of thermostats	All rooms	All rooms	All rooms	Every 3rd or 4th room	One room
Fresh water source	City	City	City	City	City
Score on HIF	24	21	20	18	17
General exterior sources of pollutants	None	None	None	None	Smoke stack ind.

(table continues)

Table 4.11

Summary of Major Findings From Case Studies

	A	B	C	D	E
General interior sources of pollutants	Gas & Oil Appliances smoking (1 room)	Central A/C smoking (1 room)	Gas Appl A/C units smoking (1 room)	Central A/C & mold	Gas Appl Smoking (1 room) poor maint.
Overall quality of indoor environment	Margin. Accept.	Acceptable	Acceptable	Acceptable	Margin. Acceptable
No. of reported health-related symptoms	16	19	17	11	5
Correlation between health-related symptoms and observed sources	None apparent	None apparent	None apparent	None	Minor
Range of temperatures in °F with (mean)	72-75 (74)	72-74 (73)	70-75 (73)	67-71 (70)	75-80 (77)
Temperature level	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable on high side
Range of relative humidities in percent with (mean)	26-31 (28)	30-44 (34)	25-35 (29)	45-51 (47)	30-40 (35)

Table 4.11

Summary of Major Findings From Case Studies

	A	B	C	D	E
Relative humidity level	Generally not accept.	Acceptable on low side	Not accept. low side	Acceptable	Acceptable on low side
Range of carbon dioxide concentrations in PPM with (mean)	700-1100 (920)	400-750 (610)	300-1700 (875)	1600-2200 (1940)	600-1000 (720)
Range of corresponding air exchange rates in CFM (mean)	28-14 (18)	140-25 (37)	400-8 (19)	8-6 (6.5)	38-16 (27)
Air exchange rate level for non-smoking areas **Exist. Std.** **Prop. Std.**	Accept. Varies by Room	Accept. Accept. by Room	Accept. Varies Accept.	Accept. Not	Accept. Accept.
Radon level	Accept.	Accept.	N/A 1 rm.	Accept.	Accept.
Formaldehyde level	Accept.	Accept.	Accept.	Accept.	Accept.
Level of maintenance	Good	Good	Good	Good	Poor
Indoor air quality problem	No overall problem	No overall problem	Possibly	Yes	Minor problem
Level of awareness of indoor air pollution	None	None	Little to none	None	None
Recommendations	Improve climatic conditions Increase awareness.	Increase awareness.	Further study needed/Improve climatic cond. Increase awareness.	Further study needed/Improve climatic cond. Increase awareness	Improve climatic conditions Improve maint. Inc. awareness.

Table 4.11

Summary of Major Findings From Case Studies

	F	G	H	I	J
Age of facility in years	30	5	8	47	6
Case study facilities in immediate area	E	A,C,I,J	D	A,C,G,J	A,C,G,I
How heated	Gas boiler	Electric boiler	Electric heat pump	Gas forced air	Electric boiler
How cooled	None (only 1 window unit)	Electric cooling unit	Electric heat pump	Window A/C units	Electric cooling unit
Location of thermostats	All rooms	Every other room	Every 4th or 5th room	Various rooms	All rooms
Fresh water source	On site well	City	City	City	City
Score on HIF	2	2	2	2	1
General exterior sources of pollutants	Well	None	None	None	None
General interior source of pollutants	Gas Appl.	Central A/C unit smoking (1 room)	Central A/C smoking (1 room)	Gas Appl Room A/C	Central A/C

(table continues)

Table 4.11

Summary of Major Findings From Case Studies

	F	G	H	I	J
Overall quality of indoor environment	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable
No. of reported health-related symptoms	None	None	None	None	None
Correlation between health-related symptoms and observed sources	None apparent	None apparent	None apparent	None apparent	None apparent
Range of temperatures in °F with (mean)	76-81 (77)	78-79 (78)	72-78 (77)	76-78 (77)	73-76 (75)
Temperature Level	Acceptable on high side	Acceptable on high side	Acceptable on high side	Acceptable on high side	Acceptable
Range of relative humidities in percent with (mean)	34-43 (39)	26-29 (28)	26-30 (27)	26-30 (28)	30-36 (34)

(table continues)

Table 4.11

Summary of Major Findings From Case Studies

	F	G	H	I	J
Relative humidity level	Acceptable on low side	Not acceptable	Not acceptable	Not Accept.	Accept. on low side
Range of carbon dioxide concentrations in PPM with (mean)	500-1300 (780)	800-1100 (960)	600-1000 (825) 1 Rm-4000	500-1000 (660)	1200-2200 (1540)
Range of corresponding air exchange rates in CFM (mean)	140-11 (23)	22-14 (17)	38-16 (21) 1 rm-3	60-16 (31)	12-6 (7)
Air exchange rate level for non-smoking areas Exist. Std.	Accept.	Accept.	Accept. ex. 1 rm.	Accept.	Accept.
Pro. Std.	Varies by rm.	Varies by rm.	Accept. ex. 1 rm.	Accept.	Not Accept.
Radon level	Accept.	Accept.	Accept.	Accept.	Accept.
Formaldehyde level	Not Measured	Accept.	Not Measured	Not Measured	Not Measured
Level of maintenance	Good	Good	Good	Good	Good
Indoor air quality problems	No overall problem	No overall problem	No overall problem	No overall problem	No overall problem

(table continues)

Table 4.11

Summary of Major Findings From Case Studies

	F	G	H	I	J
Level of awareness of indoor air pollution	None	None	None	None	Little to None
Recommendations	Improve climatic conditions. Increase awareness	Improve climatic conditions. Increase awareness	Improve climatic conditions. Increase awareness.	Improve climatic conditions. Increase awareness	Improve climatic conditions. Increase awareness.

Table 4.12

Summary of Responses By Part to the Health Information Form for the Ten Case Study Facilities

Case study facility	Total no. of outdoor sources of pollutants	Total no. of indoor sources of pollutants	Total no. of negative sensory symptoms	Total no. of health-related symptoms	Total score on the H-I-F
A	0	2	6	16	24
B	0	2	0	19	21
C	0	3	0	17	20
D	1	7	5	5	18
E	0	2	4	11	17
F	1	1	0	0	2
G	0	2	0	0	2
H	0	2	0	0	2
I	0	2	0	0	2
J	0	1	0	0	1

roughly one-half (49%) reported experiencing sensory and health-related symptoms as seen in the last part of Table 4.7. The other one-half did not report any symptoms. On the other hand, 11% of the same group reported sources of indoor pollution existing in their facilities and 85% reported not having any.

Since the sample was so small (5) it is impossible to arrive at any statistically significant findings. Generally there does not appear to be a strong relationship between the sensory or health-related symptoms and the observable potential sources of indoor air contaminants. One exception to this, as seen in Table 4.12, was the school in Case Study D. In this case, more study is needed to determine the cause(s) of the problem. This was substantiated during the actual inspection. The only other case study where health-related problems were suspected to be caused by indoor air pollution was E. The reason appeared to be an old and poorly maintained heating system. The minor health problems, however, may be alleviated once a new heating and cooling system is installed. Relative to the other three cases in this group, it would appear that, if in fact the symptoms were caused by the sources, there would be a greater percentage of them being reported by the respective schools. Also, with so many different types of symptoms being reported, one would expect to find a large number of sources than actually were found in the facilities.

In summary, it appears that the persons completing the forms, in the first group of five, were generally unsure of the type of data being requested and the reasons for it. Their awareness of indoor air pollution was very limited to nonexistent. Furthermore, the causes of the reported symptoms appeared to be either from sources not found during the inspection or reasons other than indoor air contaminants. The exception to this was the facility in Case Study E.

Of the five selected schools scoring lowest on the HIF, 4% indicated having one or more sources of indoor air contaminants while 96% reported none as seen in the last part of Table 4.10. On the other hand, virtually all (99%) reported no sensory or health-related symptoms. There appears to be a strong positive relationship between the reported sources and symptoms of indoor air pollution. As for the first group of five schools, a question can be raised about the reliability of the responses contained on the HIF. The principals and other personnel interviewed at these schools knew very little about the subject. Furthermore, problems with one or more of the climatic factors existed but were not reported on the form.

In all but one case (B), one or more climatic factors needed to be improved. In some of these cases, sensory symptoms were reported on the HIF reinforcing the findings while the balance of the forms indicated no problems when in fact there were. No clear distinction could be made relative to the comparisons among those selected schools which scored highest and those which scored lowest on the HIF. It would appear that in some cases, both the sensory and health symptoms may be caused by inadequate interior climatic conditions. Further study would be needed to substantiate this. A related finding was the fact that the participants knew very little about the operation and maintenance of the materials, equipment, and systems for their buildings.

Based on the ten case studies and the information shown in Tables 4.11 and 4.12, the following findings are presented.

1. There is a general lack of awareness among the personnel interviewed of indoor air pollution and the operation and maintenance of their buildings.

2. Problems exist with one or more of the indoor climatic factors in all but one school. This could be attributed to the reported sensory and health-related symptoms.

3. The observed known sources of indoor air contaminants were kitchen appliances, equipment used to heat and/or cool the buildings, and liquid-process copying machines. One or more of these were found in all ten schools inspected. The first two sources each had their own ventilation to exhaust any pollutants to the outdoors. Also, all but one (Case Study J) was well maintained. Furthermore, the copying machines were all located in rooms which had adequate ventilation. Therefore, with the exception of one case, this equipment does not appear to be a source of indoor

air pollution and thus not the cause of the reported health-related symptoms. This equipment was located in school buildings in both groups of five.

4. Formaldehyde was not a problem in any of the buildings monitored.

5. Radon was found to be a problem in only one room of one of the buildings monitored (Case Study C). And the concentration in this case is slightly above the lowest threshold level specified by the EPA. Further monitoring is needed.

6. Since little was known about indoor air pollution by the principals and there did not seem to be any strong positive relationship between sources and symptoms in most of the schools inspected, a question must be raised about how accurately the Health Information Forms were completed from both a standpoint of providing exact information such as the existence of known sources of indoor air contaminants in their facilities and reporting symptoms which they indicate were caused by air contaminants. This was reinforced during the actual inspections when sources which were not reported were found to exist. Furthermore, when the principals were asked what they attributed the reported health-related symptoms to, most of them responded with reasons other than air contaminants such as infectious diseases, poor climatic conditions, and reasons unknown.

The general findings under this objective which will serve as data to be included in the development of the final document for this study are:

1. The manual must be presented in an understandable manner to be useful to the principal.

2. The information contained in the manual will only act as a guide for the principal in diagnosing, alleviating, and preventing problems with indoor air pollution in his buildings. Because of the complexity of the subject matter, specialists most likely will have to be consulted as part of the overall process. This will be pointed out in the appropriate places in the manual.

3. Attention to climatic conditions will be an important part of the inspection of the building. The measurement and analysis of climatic factors should be completed prior to expending resources to perform a detailed investigation of the environment to determine if known sources of indoor air contaminants are causing the reported symptoms.

4. The design, and implementation of an effective preventive maintenance program will be discussed in the manual.

Objective 2: Develop, Field Test, and Finalize Survey Forms to be Used as Part of the Final Document Produced from this Study.

Three formats were developed for this research. They were the Health Information Form (HIF), Comprehensive

Building Survey, and Room Inspection Forms. The first was developed and used to obtain information from which a decision was made as to what schools would serve as the ten case study sites and to obtain data to be used in the development of specific statistics as described in Chapter Three. The inspection of the buildings, along with discussions with the principals and staff, provided input which was used to revise the HIF. The revision process resulted in two forms of the document. The first could be used by others to obtain data on potential sources and symptoms of indoor air pollution. The specific revisions made were:

1. Eliminate the "Don't Know" choice from those items that contained them. This choice did not provide any pertinent information for this study. Furthermore, having such a choice gives the person completing the form an excuse not to determine whether or not a specific item or symptom, in fact, exists.

2. Clarify some of the items that appeared to create confusion among those completing the form; along with adding items which were found to be missing such as the type of hot water heater.

The second revised version of the form is to be placed in the manual developed from this study to determine if and to what degree health-related and sensory symptoms exist in a building where indoor air pollution is suspected. The revisions made for this format were the same as noted for the first one, plus the following:

1. Delete Parts I and II, since the information requested in these parts would be obtained during the actual building inspection.

2. Change the directions to make the form more applicable for which it will be used.

The first revised format is contained in Appendix F. The second version is in the manual which is also contained in Appendix G of this dissertation.

The second and third original forms were used to document information obtained during the inspection process of each facility. As they were used shortcomings were identified and noted on the respective form. At the conclusion of the inspections, the comments were incorporated into the revision of both forms. The revisions can be grouped into three categories. They are:

1. Addition of information that was not included in the original formats.

2. Editorial revisions to make the forms more understandable and thus useful.

3. Deletion of data that were found not to be pertinent to the inspection process.

The revised versions of both forms will be used to diagnose and alleviate health-related problems with indoor air pollution. They are both found in the manual which is in Appendix G of this study.

Objective 3: Take Physical Measurements of Temperature, Relative Humidity, Carbon Dioxide, and the Contaminant Radon in the Ten Selected Schools and the Pollutant Formaldehyde in Five of the Ten Schools as Part of the Field Test Site process Using the Appropriate Instrumentation and Monitoring Devices that are Readily Available to the Principal.

This objective was easily attained using the instrumentation and monitoring devices discussed in Chapter Three. All of these items are readily available at a relatively low cost to the principal or other school personnel. However, as a result of the total field test study it was found that the radon and formaldehyde monitors would be of little use to the principal to perform any preliminary investigations of the air quality.

These monitors, however, would be useful if there existed suspected sources of the respective contaminant. In the case of the ten facilities inspected, there was very little evidence that either radon or formaldehyde existed. See Table 4.11 for a summary of the findings relative to these two pollutants. From an economical standpoint, an initial evaluation of the building environment, both indoors and out, should be made to ascertain if one or more sources of the specific pollutant exists. In addition, an analysis should be made to determine if there exists health-related symptoms known to be caused by the specific pollutant before monitoring for it. If it appears that the contaminant exists, appropriate monitoring should be initiated, especially if both sources and health-related symptoms caused by it exist.

Based on the above information the final document of this study will not incorporate the routine monitoring of radon, formaldehyde, or any other pollutant. This will only be suggested when evidence exists that the pollutant is in the environment or when the principal desires to embark on a prevention program by first monitoring the air for one or more pollutants to establish a base for future air quality studies. Obviously this cannot be done for all contaminants which may or may not exist due to the enormous cost involved with the monitoring and follow-up analysis process. It may be less expensive to mitigate any known sources instead of embarking on a comprehensive air monitoring program. In cases where preventive measures are performed, they should be limited to those pollutants which are less costly to monitor.

The last finding, under this objective, relates to the user of the monitoring devices. He or she should not use the devices without a thorough knowledge of their purpose and how they are used. They should be trained in all aspects of the monitoring activity. The lack of sufficient training could result in expending valuable resources without attaining the objective(s) of the monitoring activity. If such training is not available or one is not willing to take advantage of it, consultants should be employed to perform the monitoring activity.

Objective 4: Determine the Level of Awareness of Indoor Air Pollution Among the Principals of Ten Elementary Schools in South Carolina.

All ten principals had very little if no awareness of indoor air pollution and the effects it can have on the health of the buildings' occupants. The first became evident when interviewing the principals during the inspection process. They were all asked about their knowledge of the subject. Two of them had read something about it in their local newspapers but gained little from the article. All the principals (and others interviewed) wanted to know more about it.

The low to nonexistent level of awareness appeared to be a detriment to accurately completing the HIF. This was substantiated from the interviews and the inspections of the buildings. In three cases (B, F, G) potential sources of indoor air contaminants which existed were not indicated on the HIF. Furthermore, upon questioning the principals as to the reasons why specific health-related symptoms were reported, in every case reasons were mentioned other than solely those related to indoor air pollution. They did, however, indicate that part of the reasons may relate to air contaminants but were not sure. One exception to this was the building in Case Study I, where it was evident that the health-related problems were caused in whole or in part from one or more unknown pollutants in the air. Another exception was Case Study F where the heating system may be causing one or more of the reported sensory and/or health-related symptoms. The reader is referred to Table 4.11 for a summary of the case study results relating to the level of awareness issue.

Objective 5: Develop Process Which could be Used to Diagnose and Alleviate Health-Related Problems from Indoor Air Pollution in Schools.

One of the major purposes of the school building inspections was to develop and field test procedures that could be used to diagnose and alleviate health-related problems from indoor air pollution. The following were the findings from this effort which serve as the basis for the process.

1. All forms needed to be revised to be more useful to the principal in the diagnostic process.

2. The procedure to diagnose for the existence of indoor air contaminants was revised and documented in the final manual.

3. There were no opportunities to get involved in alleviating problems from indoor air pollution during the field site investigations. Therefore, the procedure to be included in the manual must come from the experience of others. In this case the needed information was obtained from the literature search.

4. The following outline was developed for the chapters in the manual dealing with diagnosis and alleviation.

a. Provide a level of awareness appropriate for a basic understanding of the subject and use of the manual.

b. Recognize when a potential problem exists with indoor air pollution.

c. Determine the extent of health-related and climatic problems within the indoor environment using the revised Health Information Form.

d. Inspect the building using the revised inspection forms to determine if any known sources and/or causes of indoor air pollution exists.

e. Measure temperatures, relative humidities, and air exchange rates within the building.

f. Compare reported negative sensory perceptions of the indoor climate to the results of the measurements in step e.

g. Compare the results of the actual measurements with ASHRAE standards and document any which do not meet the minimum requirements.

h. Compare reported health-related symptoms to sources and/or causes of indoor air pollution identified during the inspection. Document any potential positive cause-effect relationships.

i. In consultation with ventilation specialists and others make adjustments to any of the climatic factors which were found to be unacceptable and follow-up to ascertain if the reported symptoms disappeared.

j. If any symptoms still exist after performing step i, implement appropriate mitigation procedures in consultation with specialists. Then follow-up to ascertain if the previously reported symptoms have disappeared.

k. If symptoms still exist, consult with specialists. More detailed studies will be required including monitoring of the air. After each attempt is made to correct the situation a follow-up survey will be required to see if the effort was successful.

Objective 6: Identify Information Which can be Used in the Development of Guidelines for the Prevention of Problems with Indoor Air Pollution in School Buildings.

The prevention of problems with indoor air pollution begins with a thorough understanding of the subject. Therefore, one must first become aware of the topic. The findings from this study showed that those interviewed knew little about the topic.

The actual field test activities carried out did not include ones relating to prevention. However, much was learned from the literature search which can be applied in the development of a process to prevent indoor air pollution. The findings which serve as the basis for the chapter in the manual relating to prevention in existing buildings are as follows:

1. Perform a comprehensive building inspection and follow-up analysis to determine if any known causes and/or

sources of indoor air pollution exist and, if so, take the appropriate steps to mitigate them.

2. Maintain the building materials, equipment, systems, and grounds in such a manner as to prevent problems with indoor air contaminants. On a regular basis, evaluate the effectiveness of the maintenance program.

3. Monitor the daily activities occurring inside and outside the building to insure that air contaminants are not being introduced into the building.

The following findings pertain to the prevention of indoor air pollution in proposed or new construction:

1. Review the construction drawings and specifications to insure that all causes and/or sources of indoor air contaminants have been excluded. If ones are found, appropriate design changes and/or substitutions should be made.

2. Monitor the construction process to be sure no substitutions are made for materials, equipment, and/or systems which could be a source of indoor air contaminants.

3. Develop, implement, and maintain an effective preventive maintenance program for the facility. On a regular basis evaluate the effectiveness of the program and make appropriate changes.

Objective 7: Increase the Reader's Awareness of the Subject of Indoor Air Pollution in School Buildings.

As noted in the findings of many of the other objectives, there is a lack of awareness about indoor air pollution in school buildings among school personnel. Work needs to take place to create materials which can be used to increase this awareness. The information contained in this dissertation can serve as the foundation for such materials as it does for the manual contained in Appendix G. The principal should not attempt to perform any tasks relating to the diagnosis, alleviation, or prevention of indoor air pollution until he or she understands the basics of the subject.

One's awareness will also be increased as he or she becomes involved in carrying out diagnostic, alleviation, and/or prevention activities, which in turn will make him/her more effective and efficient in dealing with similar problems. Finally, awareness workshops or seminars should be designed and offered to all school personnel on the subject.

Objective 8: Suggest Areas of the Subject that Need Further Study.

The subject of indoor air pollution is very complex. This was substantiated by the information gathered from the literature search, the building inspections and other tasks performed for this study. Many areas that need further study were identified. They will be presented in Chapter Five.

Summary of Findings

The following is a summary of the various findings from this study under each objective.

Objective 1: Present a Case Analysis for Each of the Ten Schools Visited from which Qualitative-Based Conclusions will be Developed which will Serve as Data to be Included in the Development of the Final Document of this Study.

1. When a problem with indoor air pollution appears to exist, the necessary resources should be dedicated to determining if a problem exists, in fact it does, and if so, to alleviate it.

2. For one of the selected five schools (Case Study D) scoring highest on the HIF, one or more of the health-related and sensory symptoms is being caused by indoor air pollution. Further study is needed to determine the exact cause(s).

3. For one of the selected five schools (Case Study E) scoring highest on the HIF, minor health-related problems appear to be caused by an old and poorly maintained heating system. The reported planned replacement of the system probably will improve the present situation. A follow-up should be performed following its replacement to ascertain if conditions improved.

4. For all the selected five schools scoring highest on the HIF, with the exception of the one in Case Study E, the reported health-related and sensory symptoms did not appear to be caused by the observed known potential sources of indoor air pollution.

5. For the selected five schools scoring lowest on the HIF, there is a potential positive relationship between the lack of observed potential sources of indoor air pollution and no reported health-related and sensory symptoms.

6. The level of awareness of the principals and others interviewed at the ten schools about indoor air pollution was very limited to nonexistent.

7. It appears, due to the lack of awareness of the principals of indoor air pollution, that the Health Information Forms were not completed accurately and thus the reliability of their responses can be questioned.

8. The principals were all concerned about the potential problems from indoor air pollution and wanted to learn more about it. A need for a manual, such as the one developed from this study, that could be used by principals and other school personnel was thought to be a desirous document by those interviewed.

9. In all but one (Case Study B) of the ten schools inspected, the temperature, relative humidity, and/or air exchange rate was found to be inadequate (not meeting existing and/or proposed ASHRAE standards).

10. The principals knew very little about the operation and maintenance of their buildings and the materials, equipment, and systems of which they are comprised.

11. It appears that in some of the ten cases, both the health-related and sensory symptoms are being caused by inadequate indoor climatic conditions. Further, more detailed research is needed to substantiate this.

12. The previously stated findings under this objective along with those presented under the other objectives that resulted from performing the investigations of the ten

facilities served as input for the development of the final manual.

Objective 2: Develop, Field Test, and Finalize Survey Forms which will be Used as Part of the Final Document Produced from this Study.

1. As a result of information derived from the ten field test site investigations, the Health Information Form, Comprehensive Building Survey and Room Inspection Forms were revised.

2. The revised forms have been included in the manual to be used in the process to diagnose, alleviate, and/or prevent indoor air pollution in school buildings.

Objective 3: Take Physical Measurements of Temperature, Relative Humidity, Carbon Dioxide, and the Contaminant Radon in the Ten Selected Schools and the Pollutant Formaldehyde in Five of the Ten Schools as Part of the Field Test Site Process.

1. Climatic conditions were inadequate (as determined by ASHRAE current and proposed standards) in all but one of the facilities inspected.

2. Radon was found to be a problem in only one room of one building of all the ten facilities monitored. The concentration was found to be slightly above the lowest threshold level established by EPA. Additional monitoring is recommended by EPA over a year's time.

3. Formaldehyde was not found to be a problem in any of the buildings monitored.

4. Principals and other school personnel should increase their awareness of indoor air pollution and be trained in the techniques of monitoring the air and taking physical measurements before becoming involved in any of these activities.

5. Before planning and implementing any mitigation and/or air monitoring procedures, any unacceptable indoor climatic conditions should be corrected and a follow-up survey performed to ascertain if the previously reported health and/or sensory problems have disappeared.

6. Any changes to the indoor climatic conditions should be performed in consultation with a ventilation specialist.

7. Any mitigation and/or air monitoring procedures should be planned and undertaken with the assistance of specialists in the specific activity.

Objective 4: Determine the Level of Awareness of Indoor Air Pollution Among the Principals of Ten Elementary Schools in the State of South Carolina.

1. The principals and others interviewed had very little to no awareness of indoor air pollution.

2. Because of the low to nonexistent level of awareness it appears that one can question the accuracy of the responses on the Health Information Forms.

3. On a related topic, the principals had a very low level of awareness on how their buildings were operated and

maintained relative to the materials, equipment, and systems of which they are comprised.

4. The principals were concerned about indoor air pollution, desired to know more about it, and indicated a need for a document to be developed which could be used to diagnose, alleviate, and prevent indoor air contamination.

Objective 5: Develop a Process which could be Used to Diagnose and Alleviate Health-Related Problems from Indoor Air Pollution for School Buildings.

1. The investigations performed at the ten case study sites and the findings from them as described under the other objectives, provided needed information to develop a usable and understandable process to diagnose health-related problems from indoor air pollution in school buildings.

2. The information obtained from performing this study, especially that from the literature search, was used to develop a procedure to alleviate problems with indoor air pollution.

Objective 6: Identify Information which can be Used in the Development of Guidelines for the Prevention of Indoor Air Pollution in School Buildings.

1. The information obtained from performing this study, especially that from the literature search, was used to develop guidelines to prevent problems with indoor air pollution.

Objective 7: Increase the Reader's Awareness of the Subject of Indoor Air Pollution in School Buildings.

1. The reader's awareness of indoor air pollution will increase upon the reading and comprehension of the material contained in this dissertation.

2. The level of awareness will increase as the techniques presented in the manual are implemented.

Objective 8: Suggest Areas of the Subject that Need Further Study.

1. Because the subject of indoor air pollution is so new and complex, there exists hundreds of related topics on which research can be performed. Some of the major ones can be found in Chapter Five.

Chapter Five

Summary and Discussion

This chapter presents a summary of this dissertation and the findings that resulted from it. This will be followed by an interpretation of the findings, limitations of the study, and implications from the findings. Finally, areas for further research will be presented.

Summary of the Problem, Methodology and General Findings

The Problem

One of the more important goals of an effective school should be to create and maintain a pollution-free environment in order to maximize the effectiveness of the teaching and learning processes. It is the responsibility of both the school district personnel and local school building administrators and staff to insure this goal is attained. But it is the school building administrator or principal who is held accountable for this responsibility in most school systems. Therefore, it is important that he or she be aware of the potential health-related problems of indoor air pollution. Presently, there is a lack of understandable and usable information on the subject. A need exists for an effective and efficient method that can be used by the principal (and other school personnel) to diagnose, alleviate, and prevent indoor air pollution. The major objective of this dissertation was to develop a manual, based on the most current information on the subject and the results of research performed for this dissertation which can be used by the principal to insure that his facilities contain a contaminant-free environment.

The Methodology

The methodology used to carry out this study and produce the final manual consisted of performing a series of activities or tasks to obtain information that served as the basis for the final document. The tasks performed were as follows:

1. Three survey instruments were developed. The first one, Health Information Form (HIF), was designed using information obtained from the literature search performed for this study; presentations made at conferences on indoor air quality; and communications with recognized experts in the field. The second and third forms, Comprehensive Building Survey and Room Survey Forms, were developed based on previous research on the subject of building maintenance.

2. Information about the frequency of the occurrence of known sources and health-related symptoms of indoor air pollution in elementary school buildings in the State of South Carolina was obtained using the HIF. Six hundred fifty of the 816 elementary schools in the state were sent a HIF, and 329 completed forms were received, for a 51% rate of

return. The data contained on the completed forms were used to select ten schools for further study.

3. The completed Health Information Forms were scored and the ten schools which served as the case studies were selected. The first five schools selected were those that scored highest on the HIF, did not contain asbestos, and consented to take part in the follow-up study. The remaining five were those that scored lowest on the form, did not contain asbestos, consented to take part in the follow-up study, and were located in at least one of the same counties as any of those in the first group of five. In addition, a series of frequency distributions were developed from the information contained on the forms that were returned.

4. A comprehensive inspection of the ten selected facilities was performed. The Comprehensive Building Survey and Room Survey Forms were used in this process.

5. Ten case studies were developed using the information obtained from the inspection process and respective HIF.

6. The process for the final document from this study was designed. The information gathered from the various tasks was used in this step including the revision of the survey forms.

7. The final document entitled *Guidelines for Diagnosis, Alleviation, and Prevention of Indoor Air Pollution in School Buildings: A Manual for School*

Administrators was written. The manual is contained in Appendix G.

8. Areas in which further research on indoor air pollution is needed were identified.

The General Findings

The following is a list of the general findings derived from this study.

1. If a potential problem with indoor air pollution exists, the necessary resources should be dedicated to determining if in fact it does, and if so, to alleviate it.

2. For one of the selected five schools (Case Study D) scoring highest on the HIF, one or more of the health-related and sensory symptoms is being caused by indoor air pollution. Further study is needed to determine the exact cause(s).

3. For one of the selected five schools (Case Study E) scoring highest on the HIF, minor health-related problems appear to be caused by an old and poorly maintained heating system. The reported planned replacement of the system probably will improve the present situation. A follow-up study should be performed following its replacement to ascertain if conditions improved.

4. For all the selected five schools scoring highest on the HIF, with the exception of the one in Case Study E, the reported health-related and sensory symptoms did not appear to be caused by the observed known potential sources of indoor air pollution.

5. For the selected five schools scoring lowest on the HIF, there is a potential positive relationship between the lack ofobserved potential sources of indoor air pollution and no reported health-related and sensory symptoms.

6. The level of awareness of the principals and others interviewed at the ten schools about indoor air pollution was very limited to nonexistent.

7. It appears, due to the lack of awareness of the principals of indoor air pollution, that the Health Information Forms were not completed accurately.

8. The principals were all concerned about the potential problems from indoor air pollution and wanted to learn more about it. A need for a manual, such as the one developed from this study, that could be used by principals and other school personnel was thought to be a desirous document by those interviewed.

9. Principals and other school personnel should increase their awareness of indoor air pollution and be trained in the techniques of monitoring the air and taking physical measurements before becoming involved in any of these activities.

10. In all but one (Case Study B) of the ten schools inspected, the temperature, relative humidity, and/or air exchange rate was found to be inadequate (not meeting existing and/or proposed ASHRAE standards).

11. The principals knew very little about the operation and maintenance of their buildings and the materials, equipment, and systems of which they are comprised.

12. It appears that in some of the ten cases, both the health-related and sensory symptoms are being caused by inadequate indoor climatic conditions. Further, more detailed research is needed to substantiate this.

13. As a result of the information derived from the ten field test site investigations, the Health Information Form, Comprehensive Building Survey, and Room Inspection Forms were revised.

14. The revised forms have been included in the manual to be used in the process to diagnose, alleviate, and/or prevent indoor air pollution in school buildings.

15. Radon was found to be a problem in only one room of one of the facilities monitored. The concentration was found to be slightly above the lowest threshold level established by EPA. Additional monitoring is recommended by EPA over a year's time.

16. Formaldehyde was not found to be a problem in any of the buildings monitored.

17. Before planning and implementing any mitigation and/or air monitoring procedures, any unacceptable indoor climatic conditions should be corrected and a follow-up survey performed to ascertain if the previously reported health and/or sensory problems have disappeared.

18. Any changes to the indoor climatic conditions should be performed in consultation with a ventilation specialist.

19. Any mitigation and/or air monitoring procedures should be planned and undertaken with the assistance of specialists in the specific activity.

20. The information obtained from performing this study, especially that from the literature search, was used to develop a procedure to alleviate problems with indoor air pollution.

21. The information contained from performing this study, especially that from the literature search, was used to develop guidelines to prevent indoor air pollution.

22. The investigations performed at the ten case study sites, the findings from them, the results of the literature search, and other investigative activities provided the needed information to develop the final document for this study.

23. Because the subject of indoor air pollution is so new and complex, there exist hundreds of related topics on which research can be performed.

Interpretation of the Findings

Indoor air pollution in school buildings has only recently surfaced as a phenomena which must be contended with by school personnel, especially the principal. In most cases it is his/her responsibility to provide a pollution free environment within his facilities. In order to do this, he/she must be first knowledgeable about the subject of indoor air pollution and then become involved in its diagnosis, alleviation, and/or prevention.

Because the subject of indoor air pollution is so new, especially as it relates to school buildings, and is comprised of hundreds of variables, the typical school principal has very little to no knowledge about it. This was one of the major findings of this study. It is incumbent upon the leadership of the educational community in this country to devote the needed resources to create materials and experiences which will result in increasing the awareness of indoor air pollution of school personnel. The principal and others within the school district should not become involved in diagnostic, alleviation or prevention activities until he or she learns and understands its causes, the problems it can create, and how to mitigate and prevent it. For without this knowledge, any activities related to the subject in which the principal becomes involved, such as performing surveys and building inspections, will not be accomplished correctly, not to mention accurately.

An enormous amount of time and resources can be expended on determining the cause of indoor air contamination and alleviating it. Before embarking on such activities, the principal must first evaluate the existing climatic conditions within his facilities. Temperature, relative humidity and air exchange rates should be determined and compared to the designated standards such as those of ASHRAE. This task should be accomplished with the help of specialists in the field. Just as it is important for the principal to become aware of indoor air pollution, he must also understand his building, the systems within it, and how they operate. The principal needs to continuously be aware, as the administrator of his building(s), that inadequate climatic conditions will not only result in an uncomfortable environment, but also one which can attribute to a buildup of pollutants. This in turn will cause health problems among the occupants and reduce the effectiveness of the teaching/learning process. Therefore, on a seasonal basis the indoor environment needs to be evaluated and appropriate changes made to one or more of the climatic factors. This should be done with the help of ventilating specialists.

Finally, the findings from this study reinforced previous research results which indicated that the lack of a comprehensive preventive maintenance program can result in the occurrence of indoor air contaminants. Even though most of the schools visited appeared to have an effective maintenance program, most of them could be improved. This was substantiated by comments from the principals. It appears when available school funding becomes restricted, maintenance is one of the first activities that is reduced in its support. This is a mistake and can lead to becoming a causal factor of indoor air pollution.

Limitations of the Study

There were two overriding limitations throughout this dissertation. They were the complexity of the subject matter and the limited available resources to conduct this research. The complexity relates to the many variables that can affect the type and amount of indoor air pollution along with its diagnosis, alleviation, and prevention. The design, implementation, and presentation of this study had to be such as to be understandable to school personnel, especially principals. Maintaining the appropriate level throughout the dissertation insured that the information contained in the manual would be at the appropriate level for school personnel to diagnose, alleviate, and/or prevent indoor air pollution.

In terms of available resources, it was found while performing the study that large amounts of time and funds are needed to support and perform most of the activities involved in the diagnosis, alleviation, and/or prevention of indoor air pollution. This is due mainly to the complexity of the subject, the lack of specific methodology to solve specific problems, and the high cost associated with the instrumentation needed in the various activities. Both funds and time were limited as support resources for this dissertation. This is the main reason why more detailed studies were not carried out at the ten case study schools, such as the performance and evaluation of mitigation and prevention activities.

Other limitations were as follows:

1. The findings derived from the measurements of the climatic factors, radon and formaldehyde were limited in accuracy to the number taken in each building. In addition, the method used to calculate the air exchange rate is accurate to plus or minus 10%.

2. The educational and exponential background which the investigator brought to this study produced some inherent limitations (bias).

Implications of the Findings

Three major implications resulted from this study. First, school building administrators are lacking in knowledge about the physical makeup of their buildings, the operation of the mechanical, electrical, and plumbing systems within them, and how to care for the materials, equipment and grounds of which the facilities are comprised. Since the principal is responsible for the day-to-day operation of the building and is usually the first one to find out about any problems with any part of it, he or she should have a basic understanding about these factors. Current college degree programs should be revised to include at least one course on the operation and care of school buildings. Indoor air pollution can become a topic in such a course. For those practicing professionals continuing education short courses should be designed and offered. Every school board or other administering body should require all their school building administrators and other designated personnel to participate in such experiences.

The second implication has to do with previous research on the topic of indoor air pollution. Many of the findings from this study and experiences of the investigator duplicate those already performed and documented in the literature. It therefore appears that the results of the previous studies done on residential and office buildings also pertain to school buildings.

Finally, any potential problems with indoor air pollution must be dealt with on a school-specific basis. Because there are so many variables involved with indoor air quality problems, any activities associated with their diagnosis, alleviation, and/or prevention can be very time consuming and thus costly. Therefore, to utilize these resources most efficiently, principals should focus their attention on solving the specific problem utilizing the results of previous research, consultants specializing in the subject, and the experience and knowledge of others in the school system. Attempting to solve indoor air quality problems based solely on the experiences of others will not only waste existing resources, but may result in not solving them.

Areas for Further Research

The complexity of the subject matter for this study suggests literally hundreds of topics for further research. The major ones which were identified while performing this study are noted below.

1. The specific effects of specific types and concentrations of pollutants on the teaching and learning process.

2. The effects specific types of construction have on the potential for problems with indoor air pollution.

3. Detailed studies of rates of absenteeism due to different types and concentrations of indoor air pollutants.

4. How indoor air pollution specifically effects productivity.

5. Detailed studies over various time periods on how specific air contaminants alone, or in conjunction with others, and at various concentrations effect the health of building occupants; along with the identification of the specific types of health problems and symptoms.

6. Development of more effective, affordable, and usable air monitoring equipment for all indoor air contaminants, alone or in combination with others and at various concentrations over various periods of time.

7. Specific studies on how the various factors that effect indoor air pollution and its effects interact to cause health-related problems.

8. Development of methodology to differentiate whether problems are being caused by inadequate indoor climatic conditions or indoor air contaminants.

9. Study of the effects which inadequate climatic conditions have on the potential for indoor air pollution.

10. Development of nationally acceptable threshold standards for all known indoor air contaminants.

11. More effective and efficient methods of alleviating indoor air pollution for all known contaminants.

12. More effective and efficient methods of preventing indoor air pollution.

13. Development of new materials, equipment, and systems which will not be sources of indoor air pollution.

14. Development of continuous monitoring equipment for all known indoor air contaminants which can be used in school buildings.

15. Perform studies of school buildings adhering to the proposed ASHRAE air exchange standards and suspected to have problems with indoor air pollution.

16. Development of a comprehensive data base of indoor air pollution studies in school buildings.

17. Increase the awareness of school personnel in the diagnosis, alleviation, and prevention of indoor air pollution.

18. Create opportunities where the manual produced from this study is used and refined from the resulting experiences.

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APPENDICES

Appendix A

HEALTH INFORMATION FORM

Introduction

This survey form is divided into four parts. Please complete the form by providing the requested information. Return this form in the enclosed self-addressed envelope.

Part I - General Information

Date: ____________________ Name of Building: ______________________________

Name of Person Completing Form: ______________________________

Job Title: ______________________________

Address: ______________________________

____

Phone Number ______________________________

Would you like the results of this study? Yes No

Approximate age of building: __________ years.

Average number of occupants in the building during the school year:

________ Students ________ Teachers ________ Staff

1.	Does the building contain asbestos?	Yes	No	Don't Know
2.	Are there any "smoke stack" industries within one mile of the building?	Yes	No	Don't Know
3.	Is there a creek or other open body of water adjacent to the building which is accesible to the buildings' occupants?	Yes	No	Don't Know
4.	Is there a land fill or garbage dump within one mile of the building?	Yes	No	Don't Know

5. What is the source of your drinking water in the building?

Well City County Other (specify) ______________________________

Part II - Equipment, Materials & Processes in the Building

Please indicate if any of the noted equipment exists. Circle the appropriate response.

1.	Space Heaters - Kerosene:	Yes	No	Don't Know
2.	Space Heaters - Natural Gas:	Yes	No	Don't Know
3.	Gas Stoves:	Yes	No	Don't Know
4.	Humidifiers:	Yes	No	Don't Know
5.	De-Humidifiers:	Yes	No	Don't Know
6.	Electronic Air Cleaners:	Yes	No	Don't Know
7.	Do you have chemistry laboratories in the building:	Yes	No	Don't Know
8.	Do you have home economics laboratories in the building:	Yes	No	Don't Know
9.	Do you have an industrial arts shop in your building:	Yes	No	Don't Know
10.	Is smoking allowed in the building?	Yes	No	Don't Know

11. Circle the appropriate term(s) that identifies(y) your heating and cooling system within the building.

Heating: Gas-Fired Oil-Fired Coal-Fired Electric-Powered

Cooling: Gas Electrical Central Air Conditioning

Room Air Conditioners None

12. Does a formal maintenance program exist for the building, on paper? Yes No

13. What is your perception about the level of maintenance in your building?

Excellent Average Poor Non-Existant

14	As far as you know, are air filters changed regularly in your heating, ventilating and air conditioning units?	Yes	No	Don't Know
15.	Is there mold or mildew anywhere inside the building?	Yes	No	Don't Know

(Continues on Reverse Side)

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Part III - General Sensory Information

Based on what others (students, teachers and staff) who work in the building tell you about each of the following items on a general basis, what are their perceptions about each one. Please note that acceptable would mean very few or no complaints. Circle the appropriate number.

1. Building Temperature:	Cold		Acceptable		Hot
	5	4	3	2	1
2. Humidity:	Humid		Acceptable		Dry
	5	4	3	2	1
3. General Comfort:	Drafty		Acceptable		Stuffy
	5	4	3	2	1
4. Air Quality:	Stale		Acceptable		Fresh
	5	4	3	2	1
5. Odor	None		Acceptable		Strong Odor
	5	4	3	2	1
6. Overall Rating	Acceptable				Not Acceptable
Of Environment	5	4	3	2	1

Are there specific locations in the building where one or more of the above items are causing excessive complaints? If so, please indicate the item(s) and the location(s)

____

____

____

Part IV - Health Related Information

During the previous school year and/or presently, have you or others in the school building had complaints of the below noted symptoms by students, teachers and/or staff for which you could not account (i.e. not due to cold, to flu, etc.) Circle the appropriate reponse.

1. Headaches	Yes	No	Don't Know
2. Dizziness	Yes	No	Don't Know
3. Irritated Eyes	Yes	No	Don't Know
4. Irritated Nose	Yes	No	Don't Know
5. Shortness of Breath	Yes	No	Don't Know
6. Drowsiness	Yes	No	Don't Know
7. Visual Problems	Yes	No	Don't Know
8. Nausea	Yes	No	Don't Know
9. Vomiting	Yes	No	Don't Know
10. Coughing	Yes	No	Don't Know
11. Loss of Attention	Yes	No	Don't Know
12. Fatigue	Yes	No	Don't Know
13. Loss of Appetite	Yes	No	Don't Know
14. Dryness of Skin	Yes	No	Don't Know
15. Skin Irritation	Yes	No	Don't Know
16. Sore Throat	Yes	No	Don't Know
17. Tightness in Chest	Yes	No	Don't Know
18. Itching	Yes	No	Don't Know
19. Allergic Reactions	Yes	No	Don't Know
20. Diarrhea	Yes	No	Don't Know
21. Aching Joints	Yes	No	Don't Know
22. Problems Wearing Contact Lenses	Yes	No	Don't Know
23. Back Pain	Yes	No	Don't Know
24. Hearing Disturbances	Yes	No	Don't Know
25. Heartburn	Yes	No	Don't Know
26. Sneezing	Yes	No	Don't Know
27. Fever	Yes	No	Don't Know
28. Sinus Congestion	Yes	No	Don't Know

Please indicate below the months in which absenteeism was above average for the 1985-86 school year. Circle the appropriate choices.

September October November December January February March
April May

To what do you attribute the excessive rate of absence for each month circled?

Month Reason(s)

____

____

____

Would you consent to take part in a comprehensive building survey of your facilities and possible monitoring of indoor air (at no expense to your school without inconveniencing the on-going school activities and without introducing any harmful foreign substances into the building.)

Yes No

Do you have any comments about this form? If so please so indicate them.

____

____

THANK YOU Roger Liska • Clemson University • Department of Building Science •
Lee Hall • Clemson, SC 29634

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Appendix B

COMPREHENSIVE BUILDING SURVEY FORM

Part I: General Instructions

Using the guidelines, attached forms and additional blank paper on which to record all observations, tour and inspect the building and its support systems beginning with the outside of the building and than the building's interior.

Part II: Building - General Information

Building Name ______________________ Age of Building ______________

Name of Inspector ______________________ Date of Inspection __________

Number of Levels (include basement) ________

Type of Building Foundation (circle appropriate answer)

Wall and Column Footings   Slab on Grade   Other ______________

Do any of these building spaces exist (circle appropriate ones)

Basement   Crawl Space   Attic

If for any one building there exists different types of foundations please explain the extent of each and where each is located:

____

____

____

Are there one or more garages and/or storage facilities attached to the building.

Yes   No

If yes explain what is stored in them and what spaces (in terms of use) immediately adjoin them:

____

____

____

What type(s) of insulation is used in the walls ______________________

ceiling(s) ______________________ floors ______________________

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Part II - Continued

Does a cafeteria exist in the building?   Yes   No

If yes, inspect it using Form No. 1.

Where do the building occupants eat thier meals?

____

What is the source of the drinking water in the building? ________________

The waste water from the building goes to (select one)

Septic Tank   Waste Treatment Plant   Body of Water

Is there any asbestos in the building?   Yes   No

If yes, where ________________________________

____

Is smoking allowed in the building?   Yes   No

If yes, where and has special ventilation been provided ________________

____

Has there been any building rennovations made within the last two years? If so describe them.

____

____

Has an energy conservation program been implemented within the past 2 years? If so, describe what it entailed ________________________

____

____

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Part II - Continued

Review the Indoor Air Quality Health Information Form with the Principal and other appropriate personnel) and clear up any questions and attempt to determine the causes of the reported acute illness symptoms and sensory items. Furthermore identify if the symptoms are related to a specific area of the building, occur at a specific time of the day, etc. Also record the persons perceptions of the overall quality of the air in the building in general.

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Part III. Exterior Pollution Sources

Do the following exist?

Landfill within 1 mile of building	Yes	No
Smoke stack industry within 1 mile of building	Yes	No
A creek or other open body of water adjacent to the building	Yes	No

Record any specific comments on the above three questions and/or provide any other sources of pollutants which are observed outside the building

____

____

____

Rate the overall quality of the air by taking some deep breaths and note any odors:

The quality is (circle appropriate response)

Excellent Good Average Below Average Poor

Describe the existance of any odors and note their source(s):

____

____

____

Part IV. Building Exterior

For the following building exterior elements note the type of material(s) of which is constructed or made and rate the level of condition it is in by circling the appropriate response.

Walls: ____________	Good Condition & Clean	Good Condition But Needs Cleaning	Poor Condition and Needs Repai

Special Comments on Walls ______________________________

____

____

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Part IV - Continued

Doors: ______ and Frames: ______	Clean & Good Condition	Good Condition But Needs Cleaning	Poor Condition and Needs Repair

Special Comments on Doors ______

______

Windows: ______ and Frames: ______	Clean & Good Condition	Good Condition But Needs Cleaning	Poor Condition and Needs Repair

Special Comments on Windows ______

______

Roof(s) ______	Clean & Good Condition	Good Condition But Needs Cleaning	Poor Condition and Needs Repair

Special Comments on Roof(s) ______

______

______

What is the general condition of any coatings such as paint?

Good (Does Not Need) Attention	Average (Will Need Attention Soon)	Poor (Needs Immediate Attention

Special Comments on the condition of Coatings ______

______

______

Does there exist any devices which are attached to and project out from the building such as chimneys, vents, etc. Yes No

If yes, describe each and rate what condition they are in: ______

______

______

______

______

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Part IV - Continued

Provide the location of the intake makeup air vent relative to the building's air exhaust vent (be as specific as possible) and the building in general:

Describe any other items or activities on the building exterior which you may feel contributes to poor indoor air quality:

Part V: Building Interior

Using Form No. 1, inspect the rooms in the building where sources and/or causes of indoor air pollutants are suspected (this may include all the rooms). Pay particular attention to rooms containing equipment, laboratories, chemical storage and typical classroom activities. Complete one form for each room.

Part VI: Building Air Heating and Cooling Central System(s)

Present a brief description on how the building is heated and cooled by the central system (provide the type and manufacturer of the system(s)).

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Part VI - Continued

Inspect the system(s) and answer the following questions.

Type of Air Handling System: Variable Volume Self-contained

Constant Volume Other ______________

How is heat brought to each room? Water Air

How is cooling brought to each room? Water Air

The heating system is powered by: Electricity Gas Coal Oil

The cooling system is powered by: Electricity Gas Coal Oil

Approximate Age of Heating/Cooling Equipment ______________________

General appearance of air handling equipment ______________________

____

Condition of air filters in central unit(s) Good Average Poor

Condition of water filters in central unit(s) Good Average Poor

If water is used in the system, is it treated with any chemicals. Yes No

If yes, state the chemical type, and how often it is used and in what quantities:

____

____

How is the temperature controlled in the building ______________________

____

Overall condition of mechanical (furnace) room: Good Average Poor

State any condition(s) such as standing water which is seen in the room which may have an effect on the quality of air

____

____

How is the water heated for tap hot water? Electricity Gas Coal Oil

What is the condition of the hot water heater? Good Average Poor

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Part VI - Continued

Provide any other information about the condition of the central HVAC system which may have a bearing on the quality of the indoor air:

____

____

____

____

Part VII: Building Maintenance

Answer the following questions about items related to the overall maintenance in the building.

Are any of the following substances used? If so where and how often.

Liquid Cleaners: ____________________________

Powder Cleaners: ____________________________

Rug Cleaners; ____________________________

Room Deodorizers: ____________________________

Floor Stripping Compounds: ________________________

Floor Waxes ____________________________

Paints ____________________________

Insecticides: ____________________________

Pesticides: ____________________________

Other (__________): ________________________

When is the building cleaned ________________________

How often is the building cleaned ________________________

Where are all the various cleaning agents and other maintenance chemicals stored?

____

Provide any other data about the general building maintenance which may have a bearing on the quality of the indoor air.

____

____

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Part VIII: Physical Measurements In Field

Measurements Taken and Air Monitoring Devices Used

Physical Environmental Measurements:

Temperature(s): Record temperatures when and where taken

Temperature	Time Taken	Location Taken

Other temperature measurements taken in rooms and recorded on appropriate form.

Humidity: Record humidity, when and where taken

Humidity	Time Taken	Location Taken

Air Monitoring Devices: Indicate below the type of device used, what is being monitored (pollutant), where it is placed in the building and other related information.

Device #1: ______________ ; ______________________________

Device #2: ______________ ; ______________________________

Device #3: ______________ ; ______________________________

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Carbon Dioxide Measurements

Sample Number	Time Taken	Place Taken	Reading	Comments

General Comments Relating To Measurements and/or Monitoring

Names and Titles of People Interviewed:

____

____

____

____

Provide any final comments relating to the quality of the indoor air, sources, effects, etc.

____

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Appendix C

ROOM SURVEY FORM

Instructions: Using a separate form for each room, tour the facility and provide responses to all the questions. Also provide any special information which may have a bearing on the quality of the indoor air.

Room Designation ____________________ Level of Building __________

Specify the Activities Which Occur in the Room ____________________

____

Specify the types of materials of which each of the following is constructed and the condition of each in terms of appearance and cleanliness.

Wall Construction ____

Wall Finish ____

Condition of Wall Good Fair Poor

Floor Construction ____

Floor Finish ____

Condition of Floor Good Fair Poor

Ceiling Construction ____

Ceiling Finish ____

Condition of Ceiling ____

Answer the following questions if appropriate.

Is there any water stains on any of the surfaces Yes No

If yes, where are they located and what appears to be the cause __________

____

Is there any mold or mildew on any of the surfaces Yes No

If yes, where is it located and what appears to be the cause __________

____

Are there any odors in the room Yes No

If yes, describe the odor, its cause(s) and its intensity __________

____

Room Designation ____________ Level ________________

If any of the following exist respond to the questions presented for each.

Kerosene Space Heater(s) Special ventilation provided? Yes No

Condition Good Fair Poor

Natural Gas Heater(s) Special ventilation provided? Yes No

Condition Good Fair Poor

Gas Stove(s) Special ventilation provided? Yes No

Condition Good Fair Poor

Room Air Conditioning Unit(s)

Condition Good Fair Poor

Condition of Filter Good Fair Poor

Humidifier(s)

Condition Good Fair Poor

De-Humidifier(s)

Condition Good Fair Poor

Air Cleaner(s)

Condition Good Fair Poor

Wall, Ceiling and/or Floor Air Vents

Condition Good Fair Poor

Plumbing Pipes and/or Fixtures (indicate type and condition for each) ______

____

____

Lights and Fixtures (indicate type and condition for each) ____________

____

____

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Room Designation ____________ Level ________________

Note any other mechanical, electrical, plumbing device or any other item in the room which may be a source of indoor pollutants such as a microwave, laboratory equipment and state the condition of each.

____

____

____

Is there a copying machine in the room? Yes No

If yes, state type and its condition ______________________________

____

Are there any chemicals stored in the room or in rooms that open into this room? If so indicate the type of chemical(s) and what they are used for.

____

____

Do you feel the intensity of lighting is appropriate for what is going on in the room? Yes No

State any activities which occur in the room which you feel may effect the air quality in the room.

____

____

____

How is the temperature controlled for this room? ____________________

____

Rate how you feel the temperature is: Cold Acceptable Hot

Rate how you feel the quality of the air is: Stale Acceptable Fresh

Rate how you feel the humidity is: Dry Acceptable Humid

Record the temperature (if applicable) ____________

Record the humidity (if applicable) ______________

Rate the general comfort in the room: Drafty Acceptable Stuffy

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Room Designation ______________ Level _______________

Describe the types of interior room furnishings and of what material they are constructed.

____

____

____

Provide any comments which will aid in analyzing whether any activities and or materials and equipment exist which are potential sources of indoor air contaminants:

____

____

____

____

____

____

____

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Appendix D

College of Architecture
DEPARTMENT OF BUILDING SCIENCE

CLEMSON
UNIVERSITY

October 1, 1986

<title> <first> <last>
<school>
<address>
<city>, <state> <zip>

Dear <title> <last>:

The purpose of this letter is to request your help in a research project funded by Clemson University on indoor air quality in public elementary school buildings in the State of South Carolina.

The advent of energy-conserving practices and devices and the use of new synthetic materials and substances has created an increase of indoor air pollutants. The presence of air contaminants in school buildings threatens the existence of a healthy physical environment and thus can effect not only the occupants of the building but also the teaching/learning process occuring within it. Many studies have been conducted on indoor air quality; unfortunately, they have focused on residential and office type buildings. Research is needed to ascertain whether or not the findings of the studies can be extended to school buildings. In addition, methodology is presently not available which can be used by the school building principal to diagnose, alleviate and prevent health related problems of students and school personnel due to indoor air contaminants. The purpose of my study is to investigate, analyze and document the causes and health related effects of indoor air pollution in public elementary schools within our state.

The first part of the study is to obtain specific information which will be used to identify school buildings which appear to have potential problems with indoor pollutants. In this light, I would appreciate it if you would complete the enclosed Health Information Survey Form and return it to me in the enclosed stamped, self-addressed envelope by November 1, 1986. It is impmortant that I receive as many responses as possible and thus if you are not certain of some specific information requested on the form use your best judgement to answer it. If you administer more than one building, please either copy the form so you have one per building or contact me for additional ones.

For those who complete and return the form, and so indicate, information will be made available on the results of the research, including the degree of potential problems with indoor air pollution within the respective building(s). I thank you in advance for your help and if you have any questions please do not hestiate to contact me at 656-3081.

Yours truly,

Roger W. Liska
Associate Professor

RWL:pbd

CLEMSON, SOUTH CAROLINA 29631 • TELEPHONE 803 656-3081

Enclosure

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Appendix E

Dear

The purpose of this letter is two-fold. First I want to thank you for participating in the recent survey on indoor air quality in school buildings. Your information was very helpful.

The second reason for writing to you is to inform you that your school has been one of ten selected for further investigation in the second part of my research. The onsite investigation includes the following activities:

1. Tour the facilities, both indoors and out, and record the types of materials of which the building is constructed, the types of activities which are occuring in and around the facility, the types of heating, cooling, lighting and other mechanical and electrical systems in the building and the condition of all the systems and materials. I will also evaluate the level of maintenance on the facility and its support systems.
2. Place 2 or 3 non-toxic passive monitors used to detect for radon, one of the common indoor pollutants. These will be placed in areas not accessible to students or the public. The small monitors will be picked up in 7 days from the day they are activated.
3. Measure for concentrations of carbon dioxide by using small indicator tubes. This will occur before classes begin or shortly thereafter and immediately after classes are dismissed. This information will be used to evaluate ventilation efficiency. I will also take temperature and humidity measurements.
4. If sources of formaldehyde are found, a small monitoring device the size of a half dollar will be hung from the ceiling in the area in which the source is located to measure the concentration of the pollutant. This device will need to remain in place for 7 days and than will be collected.

I will need about a day to accomplish these activities. There will be no interruptions of any activities going on in the building nor any need for help from any of the school personnel. Furthermore, there will be no gases or substances released in the air. I may want to speak to the person responsible for building maintenance and those working in areas where known causes or sources of indoor contaminants exist. But I would do this at their convenience.

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I hope you are still willing for me to proceed with my study of your facility. I will contact you within the next few weeks to set up a specific date and time. If the onsite survey is acceptable please drop me a note so indicating. Upon completion of this study you will be provided with the specific outcomes. Also, all names related to your building and personnel will not be used in any written documentation without prior written approval from you. Thank you for your continuing support of this project.

Yours truly,

Roger W. Liska
Associate Professor

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Dear

I am writing this letter to followup on our telephone conversation pertaining to visiting your school for the purpose of making an on-site investigation as part of my research on indoor air quality in educational buildings in the state.

I plan to arrive at your school at 1 PM on March 12, 1986. Upon my arrival I will come directly to your office prior to beginning my investigation and review with you what I will be doing and answer any questions you may have.

I appreciate your help in my studies and look forward to meeting you.

Yours truly,

Roger Liska
Associate Professor

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Appendix F

HEALTH INFORMATION FORM

Introduction
Please complete the form by providing the requested information. Return the form to
____

PART I: General Information

Date:________________ Name of Building ______________________
Name of Person Completing Form:____________________________
Job Title:____
Address:____
____
Phone Number:____

Average number of occupants in the building during the school year:
_____Students _____Teachers _____Staff

1. Does the building contain asbestos? Yes No
2. Are there any "smoke stack" industries within one mile of the building? Yes No
3. Is there a creek or other open body of water adjacent to the building which is accessible to the building's occupants? Yes No
4. Is there a land fill or garbage dump within one mile of the building? Yes No
5. What is the source of your drinking water in the building?
   On-site Well City County Other (specify)____________

PART II: Equipment, Materials & Processes in the Building

1. Space Heaters–Kerosene: Yes No
2. Space Heaters–Natural Gas: Yes No
3. Gas Stoves: Yes No
4. Humidifiers: Yes No
5. Dehumidifiers: Yes No
6. Electronic Air Cleaners: Yes No
7. Do you have chemistry laboratories in the building? Yes No
8. Do you have home economics laboratories in the building? Yes No
9. Do you have an industrial arts shop in your building? Yes No
10. Is smoking allowed in the building? Yes No
11. Circle the appropriate term(s) that identify(ies) your heating and cooling system within the building.
    Heating: Gas-Fired Oil Fired Coal-Fired Electric Powered
    Cooling: Gas-Fired Electrical Powered Central Air Conditioning Room Air Conditioners None
12. What type of hot water heater is contained in your building?
    Gas-Fired Electric-Powered Don't have one
13. Does a formal maintenance program exist on paper for the building? Yes No
14. What is your perception about the level of maintenance in your building?
    Excellent Average Poor Non-Existent
15. As far as you know, are air filters changed regularly in your heating, ventilating, and air conditioning units? Yes No
16. Is there mold or mildew anywhere inside the building? Yes No

(Continues on Reverse Side)

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PART III: General Sensory Information

Based on what others (students, teachers and staff) who work in the building tell you about each of the following items on a general basis, what are their perceptions about each one. Please note that acceptable would mean very few or no complaints. Circle the appropriate number.

1.	Building Temperature	Cold		Acceptable		Hot
		5	4	3	2	1
2.	Humidity	Humid		Acceptable		Dry
		5	4	3	2	1
3.	General Comfort	Drafty		Acceptable		Stuffy
		5	4	3	2	1
4.	Air Quality	Stale		Acceptable		Fresh
		5	4	3	2	1
5.	Odor	None		Acceptable		Strong
		5	4	3	2	1
6.	Overall Rating of Environment	Acceptable				Not Acceptable
		5	4	3	2	1

Are there specific locations in the building where one or more of the above items are causing excessive complaints? If so, please indicate the item(s) and the location(s).______________________________

PART IV: Health Related Information

During the previous school year and/or presently, have you or others in the school building had complaints of the below noted symptoms by students, teachers and/or staff for which you could not account (i.e., not due to cold, to flue, etc.). Circle the appropriate response.

1.	Headaches	Yes	No
2.	Dizziness	Yes	No
3.	Irritated Eyes	Yes	No
4.	Irritated Nose	Yes	No
5.	Shortness of Breath	Yes	No
6.	Drowziness	Yes	No
7.	Visual Problems	Yes	No
8.	Nausea	Yes	No
9.	Vomiting	Yes	No
10.	Coughing	Yes	No
11.	Loss of Attention	Yes	No
12.	Fatigue	Yes	No
13.	Loss of Appetite	Yes	No
14.	Dryness of Skin	Yes	No
15.	Skin Irritation	Yes	No
16.	Sore Throat	Yes	No
17.	Tightness of Chest	Yes	No
18	Itching	Yes	No
19.	Allergic Reactions	Yes	No
20.	Diarrhea	Yes	No
21.	Aching Joints	Yes	No
22.	Problems Wearing Contact Lenses	Yes	No
23.	Back Pain	Yes	No
24.	Hearing Disturbances	Yes	No
25.	Heartburn	Yes	No
26.	Sneezing	Yes	No
27.	Fever	Yes	No
28.	Sinus Congestion	Yes	No

Please indicate below the months in which absenteeism was above average for the 1985-86 school year. Circle the appropriate choices.

September October November December January February

March April May

To what do you attribute the excessive rate of absence for each month circled?

Month Reason(s)

____

____

____

Do you have any comments about this form? If so, please indicate them.

____

____

____

THANK YOU

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APPENDIX C

THE DIAGNOSIS, ALLEVIATION, AND PREVENTION OF INDOOR AIR POLLUTION IN SCHOOL BUILDINGS; A MANUAL FOR SCHOOL ADMINISTRATORS

BY ROGER W. LISKA

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Chapter One

Introduction

One of the more important goals of an effective school should be to create and maintain a safe, healthy, and comfortable physical environment in order to maximize the effectiveness of the teaching and learning process. There are many factors which effect the classroom environment. Some of the major ones are the type and intensity of lighting and the temperature, relative humidity and quality of the air. Much is known about the effects of heating, cooling, ventilating and lighting on the teaching and learning processes. However, very little is known about the effects of indoor air quality. The purpose of this chapter is to present an overview of indoor air pollutants along with describing how the reader can use this manual to help him or her in diagnosing, alleviating, and/or preventing health-related problems from indoor air pollution.

Overview of Indoor Air Pollution

Most people think that air pollution is primarily an outdoor problem. But many are not aware that it can be an indoor problem as well. The advent of energy-conserving practices and devices, the use of new synthetic materials and substances, new building design methods and reduced maintenance budgets have, in many cases, reduced the quality of the indoor air. This has the effect of producing acute and chronic illnesses of many of the occupants of the effected building(s).

Prior to 1973, very little was known about the health-related affects of indoor air pollution. Because the average person spends about 90% of his or her time indoors, there was a need to find out exactly how the many contaminants affected the health of the building's occupants. Research was accelerated in this area in the early 1970s and has increased since.

The majority of the studies that have been performed to date relate mainly to office and residential buildings. There has been very little research conducted in educational facilities and that which has been done involves schools located in foreign countries where buildings and support systems differ from those in this country.

If the findings from research performed on office and residential buildings can be extended to educational facilities, it appears that indoor air pollution has the potential of:

1. causing acute upper respiratory illness resulting in increased absenteeism of students, teachers, and staff.
2. hindering the teaching/learning process that takes place in the classroom because of shorter attention spans and a high rate of irritability among students and teachers.

3. influencing the productivity of those working in the facility such as secretaries and custodial personnel.

4. decreasing the efficiency and effectiveness of the air distribution system within the building.

5. decreasing the expected lifetime of the materials and support systems from which the building is constructed.

Wherever it occurs, poor indoor air quality may be caused by contaminants which have deleterious health-related effects on the occupants of the building. Sources of indoor contaminants can be categorized into two broad areas. The first are those which are generated outdoors and infiltrate indoors. The second group consists of those that are generated indoors as a result of human activities and the emission of toxic substances from building construction materials, systems, furnishings and substances such as duplicating fluids used in the facility. In the latter case, two subgroups of pollutants can be identified. The first are those which can be found in and around buildings such as formaldehyde in particle board or organic compounds in cleaning fluids. The second group is microorganisms which may be found in heating, ventilating, and air conditioning systems.

Pollutants that are commonly found in school buildings and their sources are:

1. formaldehyde from tobacco smoke, particle board resins in furniture and panels, insulation and resins in carpeting, cloth, and adhesives.
2. radon from the ground, masonry materials, and well water.
3. asbestos and fiberglass particles from insulation and fire retardants.
4. pesticides and insecticides both inside and outside the building.
5. nitrogen oxides from kitchen appliances.
6. organic chemicals from paints and copiers.
7. microorganisms from people, plants, and animals.
8. carbon dioxide from human breathing.
9. allergens from insects and dust.

Figure 1.1 presents a summary of the most common indoor air pollutants. Figure 1.2 is a summary of the various sources for the common contaminants.

The quality of indoor air depends on many factors. The major ones include the outdoor concentration of one or more pollutants, the existence of indoor sources of pollutants, the rate of exchange of outdoor air for indoor air, the volume of space within a structure and characteristics of pollutants. To complicate the issue, these factors must be considered simultaneously.

Figure 1.1. Summary of common indoor pollutants that cause health-related problems and their originations.

Origin predominantly outdoors

- Lead
- Ozone
- Pollens
- Sulfur dioxide

Origin predominantly indoors

- Allergens
- Ammonia
- Asbestos
- Carbon dioxide
- Carbon monoxide
- Formaldehyde
- Micro-organisms (including bacteria and other infectious agents)
- Organic substances (including aldehydes, hydrocarbons and others)
- Radon
- Spores (including fungi and molds)

Figure 1.2. Sources of major indoor air contaminants

Source	Contaminant
External environment	
Water	Radon
Air	Bacteria Carbon monoxide Hydrocarbons Nitrogen oxides Sulfur dioxide Particles
Soil	Radon
Building envelope	
Particle Board	Formaldehyde
Urea-formaldehyde foam insulation	Formaldehyde
Paneling	Formaldehyde
Ceiling tile	Formaldehyde
Plywood	Formaldehyde
Concrete	Radon
Gypsum board	Radon
Environmental control systems	
Evaporative cooling device	Bacteria
Gas furnace	Carbon monoxide Nitrogen oxides Sulfur dioxide
Electronic air cleaner	Ozone
Humidifier	Bacteria Fungi

(figure continues)

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Figure 1.2. Sources of major indoor air contaminants

Source	Contaminant
Fireplace and woodstove	Carbon monoxide Benzo-a-pyrene (Organic compound) Particles Organic compounds
Unvented natural gas space heater	Carbon monoxide Nitrogen oxides Particles
Unvented kerosene space heater	Carbon monoxide Nitrogen oxides
Interior structure	
Particle board	Formaldehyde
Ceiling tile	Formaldehyde
Plywood	Formaldehyde
Paint	Hydrocarbons (nonmethane) Mercury vapor
Furnishings and appliances	
Dryers which exhaust directly into home	Particles Chemicals from fabric softeners
Carpet	Bacteria Formaldehyde
Gas stove	Carbon monoxide Aldehydes Nitrogen dioxide Nitric oxide Respirable particles
Furniture	Formaldehyde

(figure continues)

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Figure 1.2. Sources of major indoor air contaminants

Source	Contaminant
Insecticide strip	Dichlovos (organic compound)
Water	Radon
Draperies	Formaldehyde
Associated with inhabitants	
Human and animal metabolic activity	Infectious agents Allergens Ammonia Organic vapors
Cleaning with ammonia-containing cleaners	Ammonia
Vacuuming carpet	Bacteria
Clothing of asbestos workers	Asbestos
Cigarettes	Carbon monoxide Respirable particles
Human activities	Formaldehyde
Cleaning oven	Hydrocarbon gases (nonmethane)
Polishing furniture	Hydrocarbon gases (nonmethane)
Hobbies and crafts	Organic vapors
Cleaning carpet	Residue from carpet cleaner

Note. From Indoor Air Quality Handbook (Sand 82-1773) (p. 28, 31, 33, 37, 39 & 41) United States Department of Energy, 1982, Washington, D.C.

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Air contaminants come into contact with the skin and eyes. In addition, they are inhaled and less frequently ingested. They may be absorbed into the body through the skin, respiratory tract and gastrointestinal tract, and are transported throughout the body. After coming into contact with susceptible tissue, some contaminants produce adverse health affects such as irritation of the eyes and mucous membrane, interference with metabolic processes, changes in cell development, and cancer.

The technology of determining the health-related effect of a specific concentration of one or more pollutants on a certain individual is in its infancy. Recent research has shown that there are literally thousands of chemical and biological compounds which are considered potential contaminants and whose health-related effects are unknown. A specific air pollutant may produce various health effects in different people and at different times, depending on its chemical and/or biological properties, its concentration, the duration of exposure to the contaminant and the sensitivity of the person. Figure 1.3 provides a summary of the health effects of major indoor air contaminants.

When discussing the health effect(s) any one pollutant has on any one individual, one must consider the severity of the effect. The system commonly used to classify the various degrees of severity contains five separate categories. They are:

Figure 1.3. Health effects of major indoor air contaminants

Descriptive summary	Health effects
Respirable Suspended Particles (RSP)	
Particles or fibers in the air small enough to be inhaled. RSP is a broad class of chemically & physically diverse substances. Tobacco smoke is usually the largest indoor source. Other sources include fireplaces, wood stoves, unvented gas appliances, kerosene heaters, asbestos construction material, house dust.	Health effects depend on particle size and chemical composition. Primary effects of concern are nose, throat, eye irritation, respiratory infection, bronchitis, emphysema, heart disease. Asbestos fibers and tobacco smoke particles linked to lung cancer. Radon progeny attach to particles and can lodge in the lung.
Combustion gases	
Carbon monoxide (CO) and nitrogen dioxide (NO_2) are gases formed during the use of gas stoves, unvented gas & kerosene space heaters, and woodstoves. Tobacco smoke is another source. CO increases when there is an inadequate supply of combustion air; NO_2 increases with higher combustion temperature.	CO interferes with the delivery of oxygen throughout the body. oMild oxygen deficiencies can affect vision and brain function. NO_2 can irritate skin, eyes, and mucous membranes. NO_2 produces respiratory illnesses ranging from slight burning and pain in the throat and chest to violent coughing and shortness of breath. Chronic effects of long-term low-level exposure are uncertain
Allergens and pathogens	
A wide variety of bacteria, viruses, fungi, pollen, algae, etc., which can produce infection, disease or allergic reaction. Major sources are human activity and domestic animals. Excessive humidity, standing water, reduced ventilation, and use of untreated recirculating air can increase concentrations of microorganisms.	Common viral diseases (chicken pox, measles, influenza), respiratory infections, asthma, allergic reactions of the skin, nose, airways, and lungs.

(figure continues)

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Figure 1.3. Health effects of major indoor air contaminants

Descriptive summary	Health effects
Radon	
A naturally occurring radioactive gas which enters home primarily from underlying soil & rock. Other sources include drinking water and building materials.	Radon itself decays and produces radioactive decay products. If inhaled, these decay products can lodge in the lungs and irradiate surrounding tissue. Scientists estimate 5,000-20,000 lung cancer deaths per yr. in the U.S. may be due to radon.
Formaldehyde	
A strong smelling water soluble gas used as a component of some insulation and of adhesives used in making plywood, particle board, and fiberboard. Other sources include furniture, drapes, carpet, paper products.	Principal effects are eye, nose, throat irritation. Individual sensitivities vary. Long-term exposure causes nasal cancer in animals.
Organic compounds	
A wide variety of chemicals used in household products. (Cleaners, paints aerosols, deodorizers) pesticides, building materials, and furnishings. Also released by smoking, and gas or wood burning appliances.	Difficult to assess, due to variety of compounds, interactions, etc. Some are irritants, some are carcinogenic. Some affect the central nervous system, or interfere with metabolic processes.

NOTE. From Indoor Air Quality Environmental Information Handbook: Building Characteristics (Contract No. DE-AC01-81EV10450) (pp. 2-2 & 2-3) United States Department of Energy, 1987, Washington, D.C.

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1. Chronic--Long-lasting illness which can result in death. An example is cancer induced by asbestos or radon exposure.

2. Acute--Illness which exists only when exposed to the pollutant, such as watering of the eyes when exposed to formaldehyde. If acute illness is allowed to continue it can turn into chronic illness.

3. Hypersensitivity--Highly individualized reaction to one or more pollutants such as from passive cigarette smoke.

4. Impaired sense of well-being--A reaction caused by a low tolerance for specific levels of environmental conditions. An example would be a feeling of stuffiness caused by an inadequate amount of fresh air.

5. Imaginary--Illness exists only in one's mind, not physically. An example is a psychosomatic illness or a mass psychogenic illness.

Many times it is hard to differentiate among the various classifications listed above.

In terms of a real illness, the effect which any pollutant has on an individual is expressed in the form of a dose-response relationship. As noted above, responses may include acute symptoms such as headaches to more serious chronic complications such as cancer. The dose refers to the amount of pollutant inhaled or exposed to a specific part of the body. It is dependent upon the concentration of the contaminant, the rate at which the individual takes in air, and the body's clearance rate for each specific pollutant.

The problem of attempting to diagnose whether or not indoor air pollution is causing illness among the building's occupants is a multi-faceted process. A complete evaluation of the environment requires interviewing those having health-related symptoms inspecting the building inside and out, and sampling and/or monitoring of the air for the type(s) and concentration(s) of air contaminants. Interviews do not always result in obtaining factual information. This is especially the case when the person being interviewed is experiencing conflict within the organization and realizes the power he has in knowing that by giving inaccurate information he or she may be able to get changes made which would alleviate their situation. In addition, many of the symptoms which may occur as a result of being exposed to one or more air contaminants are similar to those resulting from common diseases such as colds or inadequate indoor climatic conditions such as a dry relative humidity. Furthermore, sampling and monitoring of the air may be an expensive undertaking. Finally, instrumentation does not presently exist to measure very low concentrations of one or a combination of many pollutants that may be causing health-related problems. In summary, there are literally hundreds of variables which may play a major role in determining if a specific concentration of a specific pollutant is causing health-related problems with one individual. And much is not known about some of the variables. The fact remains that all children, teachers, and school personnel must be provided with an environment which is free from hazardous concentrations of indoor air contaminants.

It is the responsibility of school district personnel and the local school building administrator to provide and maintain indoor air quality which is free from pollution. But it is the school building administrator or principal who is held accountable for this responsibility in most school systems. Therefore, it is important that he or she become aware of the potential problems of indoor air pollution, how to diagnose it, and if it exists, how to alleviate it. In addition, the principal must become aware of how to prevent its occurrence.

Purpose of Manual

The purpose of this manual is twofold. First, it serves to increase the reader's overall awareness of the problems associated with indoor air pollution. Second, it can be used as a guide to diagnose, alleviate, and prevent health-related problems from indoor air contaminants.

The contents of this manual incorporate the latest information on the subject of indoor air pollution. Many of the procedures and forms included are the result of a major study performed in school buildings. The manual has been designed to be used by professionals in all areas of education including teachers and administrators. However, it is the school building administrator or principal who, in most cases, will be responsible for initiating any action relative to diagnosing and alleviating health-related problems from potential indoor air contaminants.

Whoever uses this manual, it should first be read cover to cover. This will provide the reader with an overall knowledge of the subject the basis of an awareness program. For those who become directly involved in diagnosing, alleviating, and/or preventing health-related problems from indoor air contaminants, the chapters in this manual should be referred to in carrying out the specific tasks. This will result in a more efficient manner of dealing with the problem(s).

Since this manual has been designed to help school personnel to deal with health-related problems with indoor air pollution, it does not present detailed information about any one specific aspect of the subject. The reader is referred to the resources presented in the appendix for in-depth information on the subject. A list of definitions is also included in the appendices.

Chapter Two

Diagnosis of Indoor Air Pollution

The subject of indoor air pollution is very complex and a large amount of resources such as time, money, and personnel can be spent on determining its cause(s) and/or source(s). Before dedicating such resources, the principal needs to determine, if in fact, a problem exists. This, in itself, can be a time consuming endeavor if not performed in a systematic manner. This chapter provides the school building administrator with a methodology that has been found to be effective and efficient in determining whether or not a problem exists with indoor air pollution and, if it does, how to determine its source(s) and/or cause(s).

This discussion assumes that the principal has little education and experience with the subject matter. He/She may need, therefore, to consult with appropriate specialists during the investigation process as will be pointed out in the manual. Many of these consultants will be available from the school staff, from the school district offices, from the local, county, or state health departments, and from the surrounding community depending on the specific need. Experience of others has shown that because the subject of indoor air pollution is so new and complex, a team effort will be required to alleviate it and the health-related problems it may be causing.

Indications that a Problem Exists

The first indication that a problem exists with indoor air pollution is usually health-related complaints by the occupants of the building. This may eventually lead to a high rate of absenteeism that can be another indication of problems with indoor air contaminants. The problem may also surface as the result of performing a comprehensive inspection and evaluation of the building.

If a health-related complaint is made by a student, the teacher is probably the first to hear about it. If the complaint appears real and/or is persistent, the teacher should encourage the student (and/or his parents) to seek medical attention. On some occasions school policy may require the student to have verification that he or she did, in fact, consult with a doctor before allowing him/her back into school. This usually comes about as a result of a school policy. Teachers should be required to keep a record of any health-related complaints. Figure 2.1 can be used for this purpose. At the end of each week, the principal should receive a copy of the completed form.

Sometimes it will be a school nurse or other health professional who will be responsible for dealing with ill students. The nurse should encourage the student (and/or his parents) to seek medical attention especially for persistent illnesses. The health professional should also keep records using Figure 2.1 or a similar format and forward them on a weekly basis to the principal.

As for the teachers and staff, it is usually the principal or his designated representative who receives their health-related complaints. He in turn may encourage the person to seek medical help from their doctor depending on the nature of the complaint. The principal should also keep records of these complaints along with any related information. Figure 2.2 can be used for this task.

Since absences can be another indication of health problems caused by indoor air pollution, it, like other health-related complaints, should also be monitored. If a student or staff member is absent due to illness, it is a good idea not only to record this, but also, upon their return, to determine the reason(s) for it. This information should be documented on appropriate forms such as shown in Figures 2.1 and 2.2. Sometimes the reason(s) will be provided by a doctor. Other times the reasons may be unknown or assumed. If the latter is the case this information should also be placed on the form and noted as unknown or assumed. Every school system should have policies and procedures relating to illness and absences. These should include a formal monitoring procedure as described above. If such does not presently exist the necessary resources need to be dedicated to develop them.

Figure 2.1. Record of student absences and health-related complaints.

Week of __________ Person completing form _____________

For each absence or health-related complaint, complete the information requested under the related heading in each column. Turn the completed form into the main office before leaving work on Friday.

Student name	Complaint or reason for absence	Date of complaint or absence

Figure 2.2. Record of staff absences and health-related complaints.

Week of __________ Person completing form _____________

For each absence or health-related complaint, complete the information requested under the related heading in each column. Turn the completed form into the main office before leaving work on Friday.

Staff name	Complaint or reason for absence	Date of complaint or absence

With the increased use of computers, information on illnesses and absences can be entered into a data base program for later reference to be used in performing many types of statistical analysis such as determining the mean rate of absenteeism for the specific time period or determining the number of a specific type of complaint from the occupants of a certain room in the building.

On a weekly basis the principal should review the completed forms (or computer generated data) for both the students and staff. He should pay particular attention to:

1. Types of complaints, reported reasons for them, and the frequency of each.

2. Whether or not any of the complaints appear to be restricted to a specific room or location within the building.

3. Frequencies of absences and reasons for them.

4. Persistent health problems among the same individuals.

5. Any changes and/or similarities from one week to the next.

The reasons for examining these and similar types of information is to ascertain if there appear to be any indications that the cause of the complaints and/or absences are due to items or activities in the indoor environment and, if so, are they confined to a specific part of the building. In this review process, one should keep in mind that many indoor air contaminants cause health-related symptoms common to those from infectious diseases such as colds. Furthermore, during periods when infectious diseases exist, they could be masking problems from indoor air contaminants if, in fact, sources exist. Over time, most health-related symptoms will disappear as the individuals recuperate from their illness. Others will not. It is to these which the principal should devote his or her time.

Experience has shown that health-related symptoms caused by indoor air pollution are acute. That is, they usually disappear after a sufficient amount of time once the person leaves the building, but return when coming back into the indoor environment. However, this is not always the case, since some indoor air contaminants can have a longer lasting effect on an individual, especially if the person is hypersensitive to the existing pollutant(s). Keep in mind that indoor air pollution may only affect a very few people in the building and each one may react in a different manner depending on their sensitivity to the contaminant(s).

At times it may be found that a person is reporting health-related symptoms that are psychologically induced. This may be the case when a person does not want to be in the building because he or she is having problems with others in the same environment such as a fellow student or another teacher. Sometimes the person brings a psychological problem into the environment and reports having certain health-related symptoms as a result of the way the person deals with it. In most cases the recognition that the reported health-related symptoms are psychologically induced takes time to materialize. If a psychological problem appears to exist, the principal needs to refer the student (and/or his parents) to a trained professional to determine and solve the problem.

The reader should keep in mind that some indoor air contaminants such as radon cause chronic illness that doesn't appear until it has caused extensive and irreversible damage to one's health, such as cancer. The only way to prevent such catastrophic illness is to perform a comprehensive inspection and evaluation of the building using the methodology presented in the next section of this chapter. This will serve as a baseline for all future indoor air quality investigations within the building.

If the review of existing health-related complaints and/or absences appears to be caused by indoor air pollution, the next step is to inspect the building for possible sources and/or causes. This might also be done as a precautionary step even if there are no health problems.

Inspecting the Building

The goal of the inspection is to determine if the reported health-related problems within the building are being caused by existing known sources and/or causes of indoor air pollution. The investigator should keep in mind that previous studies on indoor air quality have shown that the causes for reported health-related problems may be attributed to inadequate indoor climatic conditions such as extreme temperatures, relative humidities, and/or inadequate rates of air exchange. If climatic conditions are not at an acceptable level, they can cause health-related symptoms similar to those created by indoor air contaminants for some people. Furthermore, low rates of air exchange can allow for the building of air pollutants within the interior environment resulting in an increased potential for health problems.

A comprehensive building inspection involves determining the following information:

1. the extent of health-related problems of the occupants of the building.

2. the occupant's perceptions of the climatic conditions within the building (i.e., the temperature, relative humidity, and quality of the air that relates to the rate of air exchange).

3. whether or not there exists any materials, systems, and/or activities within the building that are known sources and/or causes of indoor air contamination.

4. temperatures, relative humidities, and air exchange rates within the building.

The magnitude of the inspection process will be up to the principal and the resources he has available to him. Some of the variables to be considered in this decision are:

1. size of the school in terms of space and number of occupants.

2. knowledge and experience of the principal pertaining to the inspection process and the interpretation of the data obtained from it.

3. available resources such as time, money, and personnel.

4. responsibilities of the principal.

On one hand, the principal can physically perform the survey himself, consulting with others as the need arises. On the other hand, he can delegate the responsibility to others within his organization. Whichever way, the more time and effort placed into the inspection activity, the better will be the resulting information from which to make further decisions. Many of the activities involved in the inspection process can occur concurrently.

The first two objectives are accomplished by surveying the occupants of the building. This can be accomplished either informally by talking with some of them, or more formally through the implementation of a building-wide survey. The latter method will result in more reliable information. Whichever method is used the form shown in Figure 2.3 should be used to document the results of this activity. If a formal survey is to be used in obtaining this information the noted form can be reproduced in the required quantity, completed by as many of the occupants as practical,

Figure 2.3. Health Information Form

Directions: Complete this form by providing the requested information.

Part I — Sensory information
What are your feelings about each one of the following climatic factors in your building? Circle the number which most closely represents your feelings on each.

1. Building temperature	Cold		Acceptable		Hot
	5	4	3	2	1
2. Humidity	Humid		Acceptable		Dry
	5	4	3	2	1
3. General comfort	Drafty		Acceptable		Stuffy
	5	4	3	2	1
4. Air quality	Stale		Acceptable		Fresh
	5	4	3	2	1
5. Odor	None		Acceptable		Strong
	5	4	3	2	1
6. Overall rating of Environment	Acceptable				Not acceptable
	5	4	3	2	1

Are there specific locations in the building where one or more of the above items are causing excessive complaints? If so, please indicate the item(s) and the location(s).

____

Part II — Health information
Have you experienced any of the following symptoms within the past three months while in the school building? Circle the appropriate response for each item.

1. Headaches	Yes	No
2. Dizziness	Yes	No
3. Irritated eyes	Yes	No
4. Irritated nose	Yes	No
5. Shortness of breath	Yes	No
6. Drowziness	Yes	No
7. Visual problems	Yes	No
8. Nausea	Yes	No
9. Vomiting	Yes	No
10. Coughing	Yes	No
11. Loss of attention	Yes	No

(figure continues)

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Figure 2.3. Health and sensory survey form

12.	Fatigue	Yes	No
13.	Loss of appetite	Yes	No
14.	Dryness of skin	Yes	No
15.	Skin irritation	Yes	No
16.	Sore throat	Yes	No
17.	Tightness of chest	Yes	No
18.	Itching	Yes	No
19.	Allergic reactions	Yes	No
20.	Diarrhea	Yes	No
21.	Aching joints	Yes	No
22.	Problems wearing contact lenses	Yes	No
23.	Back pain	Yes	No
24.	Hearing disturbances	Yes	No
25.	Heartburn	Yes	No
26.	Sneezing	Yes	No
27.	Fever	Yes	No
28.	Sinus congestion	Yes	No

and summarized. Once the results of the survey are compiled, they can be used in the analysis with the other data obtained from the inspection.

The third and fourth objectives can be attained by performing a physical inspection of the building. The Comprehensive Building Survey and Room Inspection forms can be used for this task. The forms are contained in Appendices B and C. Using the first form, the principal or his designated representative should inspect the specified materials, systems, equipment, and related items. He or she should record not only the requested information but also related data which may have some bearing on the quality of the indoor air. In addition, the results of any discussions had with any of the building's occupants should also be recorded in the appropriate space. This form also contains room to summarize any measurements taken such as temperature and relative humidity. Use additional sheets of paper or the back of the form when more space is required to record pertinent information.

Once the first form is completed, the next step is to inspect every room in the building using the second one. The inspector records his responses to the various items as the inspection of each room is performed. One form is used for each room inspected. He should also record the results of any discussions he has with the occupants of any of the rooms.

When inspecting the rooms, the inspector should measure the temperature, relative humidity and concentration of carbon dioxide (a measure related to the air exchange rate). The temperature and relative humidity can be measured using an electronic digital hygrometer. The number of readings of either of the two parameters will depend on the amount of time and resources available to perform the task. The measurements should be made near the center of the room at three to five feet above the floor level. At least one reading for each room inspected should be taken.

The Sensidyne Gastec Pump and extra low-range carbon dioxide indicator tubes can be used to take air samples to determine the concentration of carbon dioxide. At least one sample should be taken in each room inhabited by students and/or teachers and staff (i.e., one does not have to determine the level of carbon dioxide in a mechanical room which is rarely occupied). The air sample should be taken in the same region as for the temperature and relative humidity measurements.

To convert the concentration of carbon dioxide into rate of air exchange, follow the below noted procedure. An example has been provided to clarify the procedure.

$$\text{Rate of Air Exchange} = \frac{1.05}{\dfrac{\text{Concentration in ppm}}{10{,}000} - 0.0325}$$

Example: Determine the rate of air exchange for a concentration of carbon dioxide of 1200 ppm.

$$\text{Rate of Air Exchange} = \frac{1.05}{\frac{1200}{10{,}000} - 0.0325}$$

$$= \frac{1.05}{0.12 - 0.0325}$$

= 12 cfm per person

Record the results of all three measurements in the appropriate place on both forms.

Analyzing the Information

Once the entire facility has been inspected and forms completed, the next step is to analyze the data to determine if there are potential causes and/or sources of indoor air pollution. The analysis involves the following tasks:

1. Determine if there is a positive relationship between the occupant's negative perceptions of the indoor climate and the existence of unacceptable temperatures, relative humidities, and/or air exchange rates.

2. Determine if there is a positive relationship between the reported health-related symptoms and the existence of one or more sources and/or causes of indoor air pollution. Since experience has shown that most indoor air quality problems relate to the temperature, relative humidity and rate of air exchange, these should be examined first.

Research has shown that the comfort level in school buildings depend on many variables including the type of clothing worn by the occupants and their level of physical activity. ASHRAE has recommended standards which state that temperatures should be between 67°F and 80°F, and relative humidities between 30% and 70%. The investigator should compare the range of temperatures and relative humidities which exist against the ASHRAE standards and note any situations which do not comply to the standards.

Relative to the air exchange rate the present ASHRAE minimum recommendations can be found in Figure 2.4. The corresponding concentrations of carbon dioxide are shown adjacent to each air exchange rate in parentheses. Because of the recent concern for the quality of the indoor air, new minimum recommendations are being proposed and will most likely be adopted in the near future. It is recommended that the proposed rates be adhered to as a minimum in all school buildings. See Figure 2.5 for the proposed rates and corresponding carbon dioxide levels. Using Figure 2.5, the investigator should compare the measured levels to the proposed ASHRAE standards. If any of them fall below the minimum, it should be so noted.

As part of the analysis of the existing temperatures, relative humidities, and carbon dioxide concentrations, the investigator should review the responses from the HIF to

Figure 2.4. ASHRAE 1981-61 ventilation standards for school buildings.

Room type	Outdoor air requirements—CFM/ppm and equivalent carbon dioxide concentrations in PPM	
	Smoking	*Non-Smoking*
Classrooms	25(745)	5(2425)
Labs	--	10(1375)
Training shops	35(625)	7(1825)
Music Room	35(625)	7(1825)
Libraries	--	5(2425)

NOTE. From *Ventilation for Acceptable Indoor Air Quality* (p. 9) American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Standard 62-1981.

Figure 2.5. ASHRAE 1981-61 proposed ventilation standards for school buildings.

Room type	Outdoor air requirements-CFM/person and equivalent carbon dioxide concentrations in PPM
Classrooms, music rooms, libraries and auditoriums. No smoking allowed.	15(1050)
Laboratories and training shops. No smoking allowed.	20(850)
Smoking areas	60(500)

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ascertain if the sensory perceptions of those surveyed support the results of the measurements. For example, if high temperatures and/or low relative humidities exist, a stuffy feeling will most likely be reported by the occupants of the building. If a positive relationship exists, a ventilation specialist should be consulted as described in the next chapter to alleviate the problem(s).

The next step in the analysis is to review the results of the inspection to identify if any known sources and/or causes of indoor air contaminants exist. The principal should use Figure 1.2 in this process. Any causes and/or sources that are found should be noted along with their location in the building. This information should be documented on a separate sheet of paper.

Once this task has been completed the principal should compare any reported health-related symptoms to any identified sources and/or causes of indoor air contamination and determine if any positive relationships exist. For example, it is known that certain people exposed to a high enough concentration of formaldehyde contained in particle board may experience headaches. Therefore, if headaches are reported to exist and particle board is found during the inspection, there is a good likelihood that the health-related complaint is being caused by formaldehyde. The principal can use Figure 1.3 in making the necessary comparisons. Any positive relationships should be documented for later use.

If the results of the building inspection indicate a poor level of maintenance, as evidenced by poor condition of materials, systems and/or equipment, this may be a contributing factor to poor indoor air quality, especially if the air handling system is not being well maintained. If the principal finds that this is the case during the analysis stage, he should so document this fact for future use.

At this point, the analysis may become involved. What happens if one or more sources and/or causes are found, but no consistent symptoms are reported? What does one do if no causes and/or sources are found, but one or more symptoms exist? And what happens if more than one cause and/or source exists along with symptoms which could be caused by any of the sources?

If one or more sources and/or causes are identified during the inspection but health-related symptoms known to be caused by them are not reported, steps should be taken to prevent them from causing any health problems as discussed in the next chapter.

If there exists reported symptoms, but no sources and/or causes were identified, more detailed study of the environment may be needed utilizing trained and experienced consultants. This should not be done, however, until any needed improvements are made to the temperature, relative humidity, and/or air exchange rate and follow-up evaluation made to determine whether or not the improvements resulted in correcting the poor indoor air quality and thus possibly eliminating the reported health-related complaints.

Finally, if there are many health-related symptoms being reported and various sources and/or causes of indoor air pollution identified, all the possible positive relationships should be documented for use in alleviating the potential problems as described in the next chapter.

Chapter Three

Alleviating Indoor Air Pollution

If one or more actual or suspected problem with indoor air contaminants is identified during the investigation stage, steps need to be taken to alleviate them. This task can become very complex and costly. This chapter will present a systematic method that can be used by the principal either alone or with the help of others to eliminate any existing or potential problems with indoor air pollution.

Improving Indoor Climatic Conditions

Since experience has shown that the majority of problems with indoor air quality relate to unacceptable climatic conditions, the first step is to make any needed improvements in this area as described herein. If the existing temperatures, relative humidities, and/or air exchange rates do not meet the specific ASHRAE standards, appropriate action should be taken to correct the condition(s). A ventilation specialist must be consulted in making any changes. The principal should not attempt to make any changes alone.

If a low level of maintenance was identified during the building inspection, the existing maintenance program should be reviewed and evaluated. Appropriate measures should be taken to improve its weaknesses such as providing training to the staff or adding more personnel. This should be performed along with making any needed improvements to the climatic conditions within the building but before a follow-up survey is done.

Once the climatic conditions are improved, a follow-up survey should be performed to determine whether or not the previously reported negative symptoms have disappeared. If they have, no further action is needed with the exception of implementing preventive measures as discussed in Chapter Four. If, however, the occupants of the building continue to complain about climatic conditions and/or their health, the principal needs to continue to alleviate the problem as described in the balance of this chapter.

Mitigation Procedures

If there are no climate-related problems with the interior environment and health-related symptoms exist, the next step is to mitigate the previously identified cause(s) and/or source(s) of indoor air contaminants. This process begins with an understanding of the various mitigation techniques. There are two basic methods of mitigating indoor air pollution: source emission reduction and air concentration reduction. The first method consists of a number of possibilities. They are:

1. removal of the source or substitution.
2. change of design.
3. encapsulation such as covering the surface with an impermeable surface-coating.

4. confining the source to an area with limited air exchange from the rest of the building.

5. minimizing source use to reduce contamination when people are exposed.

All of these methods will require the use of specialists trained and experienced in the specific technique. See Figure 3.1 for methods of source alteration.

The second basic method is accomplished by either increasing the rate of air exchange or decreasing the concentration of the pollutant(s). The first way was previously discussed in this chapter. To reduce the concentration of contaminants, one can use mechanical filtration, absorbing surfaces or electrostatic precipitators. The adoption and implementation of any of these methods will require specialists to design and install the equipment. See Figure 3.2 for methods of contaminant removal by the air concentration reduction method.

The actual method selected should be based on a complete analysis of the specific situation. The variables that should be considered are the pollutant(s) to be eliminated, source and/or cause, adaptability of method to source and pollutant, direct and indirect cost of performing the mitigation technique, accessibility of source, ongoing activities adjacent to source, resources required and their availability, and others. If the specific situation is life-threatening, measures must be taken, no matter what the cost,

Figure 3.1. Methods of source alteration to reduce indoor contamination.

Method	Description	Potential Applicability
	Source modification	
Removal of substitution	Source of contaminant is removed from dwelling; it is replaced by a less contaminating source that fulfills the same basic function if one is required and available.	All sources
Change in design	Source of contaminant is altered in its design so that it will have a lower emission.	All sources
Encapsulation	Source is covered by a material that is impermeable to the contaminant and restricts introduction of contaminant into the indoor air	Continuous non-mechanical sources
	Source usage	
Spatial confinement	Source is used in a confined area that has limited air exchange with remainder of the dwelling	Localized sources
Temporal use	Source is used only when few people will be exposed to the contaminant and/or when the contaminant concentration can be reduced by removal (See Table 20)	Inhabitant-controlled sources

NOTE. From Indoor Air Quality Handbook (Sand 82-1773) (p. 86) United States Department of Energy, 1982, Washington, D.C.

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Figure 3.2. Methods of contaminant removal to reduce indoor air contamination.

Method	Description	Potential applicability
	Air exchange	
Infiltration and exfiltration	General exchange of indoor iand outdoor air through cracks moves a portion of indoor contaminants to outside; it may also move outdoor contaminants indoors	All contaminants
Natural ventilation	General exchange of indoor and outdoor air by intentionally opened windows, doors, and vents moves a portion of indoor contaminants to outside; it may also move outdoor contaminants indoors	All contaminants
Mechanical ventilation	General exchange of indoor and outdoor air by forced-air movement moves a portion of indoor contaminants to outside; it may also move outdoor contaminants indoors	All contaminants
Local ventilation	Movement of indoor contaminants from a specific source to the outside by natural or mechanical ventilation	Contaminants localized sources
	Air cleaning	
Mechanical filtration	Particles are trapped as air passes through a filter	Particles
Adsorption	Gaseous contaminants are adsorbed on materials with large surface areas such as activated charcoal alumina, and silica gel	Some organic gases and vapors
Electrostatic interaction	Particles become changed as they interact with ions or pass through an electric field and are removed from the air by becoming attached to oppositely charged surfaces	Particles

NOTE. From Indoor Air Quality Handbook (Sand 82-1773) (p. 88) United States Dept, of Energy, 1982, Washington, D.C.

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to correct it, including moving the affected occupants out of the building. The process becomes more complicated when the situation is causing acute or lesser-type health problems. There are no clear and concise avenues to alleviate the problem in this case. A trial-and-error method would be applied.

In summary, the principal, in consultation with others, must select one of the mitigation procedures suggested and implement it. Since a trial-and-error method will be used, the first attempt should be to remove the source or cause from the building. For some items or activities, such as cleaning substances or stripping paint from furniture, this is a viable solution. However, for other items or activities, removal would not be possible. In this case, a cost analysis should be performed to determine what it would cost to perform some of the remaining alternatives listed in Figures 3.1 and 3.2. The most economical one should be tried next. The reader should keep in mind that if only a few people are being affected by the indoor environment it may be possible to move them to another area of the building or another building, thus solving the problem economically.

Whatever method is selected, follow-up action is required to determine if it was successful. To accomplish this, the principal will need to survey the occupants to ascertain if the health-related symptoms have disappeared.

If they have, the mitigation technique was successful. If not, the next most economical method must be tried.

If the available techniques fail to mitigate the problem, it might be that there are other pollutants existing, the sources and/or causes of which have not been identified. In this case, the air will need to be monitored to determine the exact type of pollutant(s) which exist along with their concentration(s). This is a relatively costly undertaking and requires the use of experienced and trained consultants. It is beyond the scope of this manual to provide details on air monitoring procedures. However, it is important for the principal to have a basic understanding of the process.

Air Monitoring

Once it has been determined that air quality measurements are needed, a plan or design should be established for monitoring the pollutants. The first part of the plan is to develop monitoring objectives. They indicate what pollutants are to be monitored, what is the relative importance of each contaminant if more than one, what are other factors to be measured, and what are some design alternatives that might be considered.

Indoor measurement of air contamination requires consideration of a variety of factors. These include the selection of air sampling equipment and an analytical technique with an adequate sensitivity, selection of a meaningful time scale for the measurements, the calibration of sampling and analytical methods, consideration of the effects of human activities on the level of the pollutant(s) being measured.

The second part of the plan, therefore, is to identify available instrumentation and where and when the measurements will be taken. The latter information will be project specific and includes seasons of the year, time and day of the week, and spaces (buildings and/or rooms), and geographic areas to be monitored.

When reviewing the various types of instruments available, one must consider certain factors. These are mobility, operating characteristics, output characteristics, and whether the instrument is available as a unit or must be assembled from a number of commercially available units. Relative to mobility, there are three classifications: personal, portable, and stationary. The personal device is one that is worn by individuals in the environment being monitored. The other two cannot be worn due to their size and weight. As noted, one can be easily moved from location to location (portable) and the other because of its size cannot (stationary).

Within each mobility class one can further classify the instrumentation by its operating characteristics. Some devices are active in that they require a power source to draw air into a sensor or collector. The balance are classified as passive since no power is required. In this case, the sample is collected by diffusion; that is, the pollutants contained in the air settle out on a medium that has been designed to indicate, with or without further testing, whether or not the contaminants exist.

In terms of output characteristics, there are two classes. The first is a collector-type device. This instrument only collects an air sample that must be sent to a laboratory for analysis. The other classes is referred to as an analyzer device. This unit produces instantaneous results by analyzing the air sample as it is drawn into it and providing the user with the information on the concentration level of the pollutant.

Which device to use will depend on the specific project, the pollutants to be monitored, the concentrations to be monitored, and available resources such as time, personnel, and money. One must also consider ongoing activities in the facility to be monitored and whether or not they can be interrupted. It should be noted that instruments presently do not exist to monitor all concentrations of all known pollutants. Furthermore, it is not possible to measure very low concentrations of combinations of specific pollutants which may be causing health-related problems. It is beyond the scope of this manual to present detailed information about the various specific types of monitoring instrumentation and their operation. The principal should consult with specialists who are trained and experienced in this area.

Once the monitoring design objectives have been finalized and the appropriate instrumentation has been selected, the next step is to monitor the air. This should be done in accordance with the protocol established for the project by a consultant. The various aspects to be included are sample size, sampling time, sampling location, setting up and operating monitoring devices, obtaining and recording data from devices, procuring and sending air samples to the laboratory for analysis and results thereof, maintaining and calibrating instrumentation, performing quality control and assurance activities, and the development of appropriate use of forms or other documentation.

The final step is to compare the results of the monitoring with threshold or acceptable limits for the specific pollutant. Presently standards only exist for outdoor pollutants which have been developed by the Environmental Protection Agency. These standards have been accepted by the public and are used as the basis for all outdoor pollution measurement and evaluation work. They are also used as a beginning point (especially if no other data are available) when analyzing the existence of pollutants within buildings. Acceptable air-quality standards for nonindustrial type building interiors have not been established. Many organizations, both public and private,

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are working to develop such standards. Many of these appear in Figure 3.3.

The extent of the monitoring activity will depend on the resources available. Specialists can help reduce excessive use of resources. Once the pollutant or pollutants have been identified, the next step is to locate the source(s) and/or cause(s) and implement appropriate mitigation procedures as described earlier in this chapter.

The question of whether to first implement mitigation procedures on a trial-and-error basis in hopes of alleviating the problem or monitoring the air first in an attempt to identify the actual pollutant(s) and their concentration(s) followed by mitigation procedures can only be answered for each indoor air quality problem. A thorough study and cost analysis of the various solutions involving input from others should be performed before taking any action. No matter what is done, after each attempt to alleviate the problem, a follow-up survey should be done to see if the reported health-related problems have disappeared before attempting another potential solution. The reader is referred to the Appendix D for a list of companies who specialize in indoor air pollution problems. It is also recommended that the principal contact the local and/or state health departments and environmental protection agencies for names of similar specialists in their area and/or state.

Figure 3.3. Threshold concentrations of major indoor air contaminants.

Pollutant	Level	Standards and guidelines
Radon and Radon daughters	4 pCi/l 5 pCi/l 5.4 pCi/l	EPA guideline for indoor conentration BPA action level for residential weatherization program ASHRAE recommended exposure level in residences
Formaldehyde and other organic compounds	0.05 to 0.4 ppm	Proposed indoor air standards for formaldehyde compounds in some states
Nitrogen oxides	0.056 ppm 0.25 ppm	EPA average one year outdoor air quality limit for nitrogen dioxide California one-hour standard for nitrogen dioxide
Carbon oxides	9 ppm 35 ppm	EPA average eight hour outdoor air quality limit for carbon monoxide EPA average one hour outdoor air quality limit limit for carbon monoxide
Inhalable particles	5000 µg/m^3 260 µg/m^3	OSHA eight-hour average limit for respirable inert or nuisance dust EPA twenty-four hour ambient air quality standard for total suspended particles
Allergins and pathogens		none

Note. From *Indoor Air Quality Environmental Information Handbook: Building System Characteristics* (Contract No. DE-AC01-81EV10450) (pp. 1-2). United States Dept. of Energy, 1987, Washington, D.C.

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Chapter Four

Preventing Indoor Air Pollution

The prevention of health-related problems from indoor air pollution can occur both before a building is constructed or renovated and during its use. Whenever it occurs, the necessary time and resources must be dedicated to the effort. This chapter will present guidelines which the principal can use in establishing a comprehensive prevention program for his or her school buildings.

Prevention in New Construction

In the case of new construction (including renovation and remodeling), the prevention process begins with the selection of a design professional who has experience and knowledge of indoor air pollution in school buildings. He or she should be required to design the new construction utilizing materials, equipment, and systems which are known _not_ to be sources of indoor air contaminants. To be sure the architect or designer has fulfilled his responsibility, it is important that the principal or his designated representative review the construction drawings and specifications. The information contained in Figure 1.2 (see Chapter One), can be used by both the architect and principal in the review process.

If upon making the review the principal identifies any sources, they should be documented and brought to the attention of the design professional who, in turn, should select substitute materials, equipment and/or systems which are known not to be sources of indoor air contaminants. It is important that the architect work closely with the appropriate school personnel in the development of the final drawings and specifications.

In some cases there are only certain types of a specific material or equipment that can cause problems with indoor air pollution. An example is a specific type of particle board or carpet. In addition, the specifications or drawings may not specify a specific type and it will be up to the architect and/or designated school personnel to select the type as the building is being constructed. In this case, care must be taken to insure that the type selected is one which will not cause problems. The architect will have to work closely with the supplier and/or manufacturer in this case. An example is building board. Some types have high amounts of formaldehyde in them which will be released into the building once installed. It should be the design professional's responsibility to be sure they are using board that has a low formaldehyde rating.

Related concerns are is the type and operating characteristics of the building's air handling system. in today's energy conservation conscious world, too often air handling systems are specified that operate at minimum air exchange ratings. As pointed out earlier in this manual, present ASHRAE recommended air exchange rates have been found to be insufficient in recent tests creating many problems with indoor air quality. The proposed standards will improve the situation.

It is recommended that when reviewing the installation of a new system that the proposed standards shown in Figure 2.5 be followed. In addition, the system should maintain the levels of temperature and relative humidity within the recommended ASHRAE guidelines. The reader should note that taking this action doesn't mean that energy costs will be automatically increased. Current technology has introduced many new pieces of equipment such as air-to-air heat exchangers that can be incorporated into the total air handling system with the objective of minimizing the costs of heating and cooling a building.

Other things that should be considered when reviewing the entire air exchange system is filtration and localized mechanical ventilation. If there appears to be potential problems within any one room or area of the building with particles being introduced into the air, filters should be incorporated into the air handling system. The filters referred to are special ones unlike the standard filters found in most systems. These could be special electrostatic filters, fluid bed filters or some other types. However, the reader must keep in mind that these special systems can be the cause of indoor air contamination if not maintained as per the manufacturer's recommendations.

A third item that should be considered in preventing problems with indoor air pollution is the development of a comprehensive maintenance program. The program begins with the establishment of an inventory of all materials and systems of which the building is comprised. The inventory can be placed in a manual format or on computer. It would include information about each building component such as type, manufacturer, maintenance recommendations and dates when inspection and preventive maintenance activities should be and are performed. The best time to organize the inventory is during the design and construction of the facility. It should be the responsibility of the architect to provide such information to the school district as part of his or her contract for services. Even though it can be done, it is difficult and time consuming to develop an inventory after the construction has been completed. The information in the inventory serves as a resource for the principal to use in the event that indoor air pollutants are suspected to be causing health-related problems.

Once the inventory has been established, the next step is to design and implement an effective and efficient preventive maintenance program for the facility based on the recommendations of the manufacturers of the various materials and equipment in the building and other building and maintenance professionals. To be effective the program should be in writing. There should exist maintenance (including housekeeping) procedures for all the building's materials, equipment, and systems. The procedures should include frequencies on how often the procedure should be performed. In addition, an effective program provides for regular inspections and procedures for follow-up on items found to be in need of maintenance. The building, its elements, and systems should be inspected at least once a year. Some maintenance activities need to be performed daily, such as sweeping floors, some monthly maintenance such as changing air filters, and some annual maintenance such as cleaning of kitchen stoves. A comprehensive program must exist that takes all of these factors into consideration. The program should include forms that can be used in inspecting and maintaining the facility along with evaluating the effectiveness of the entire maintenance program. For specific information in establishing a comprehensive preventive maintenance program, refer to Building and Plant Maintenance Deskbooks (Liska, 1980).

Prevention in Existing Buildings

Relative to preventing problems with indoor air pollution in existing buildings, the first step is to perform a comprehensive inspection to determine if there exists any known sources and/or causes of indoor air contamination.

This process should be performed as described in Chapter Two of this manual. If sources and/or causes are found, they should be eliminated as described in Chapter Three. As part of this process, the principal should evaluate the effectiveness of the maintenance program being used in his buildings. If deficiencies are found, appropriate measures should be taken to improve the program.

Once corrective steps have been taken, school personnel should be sure that sources and/or causes are not introduced into the school environment. This requires that all teachers and staff have knowledge about the diagnosis, alleviation, and prevention of indoor air pollution. Since changes will occur in the building, it is important that the performance of the existing air distribution system(s) and equipment be evaluated prior to making any changes and updated, if found to be inadequate, to prevent any problems from indoor air contaminants. It may also be necessary to change the frequency of maintenance on the system(s).

It is also important for the principal and/or other designated school personnel to keep abreast of current research findings on the subject of indoor air pollution and make any needed changes within the buildings consistent with any pertinent findings. The principal is referred to Figure 4.1 for control techniques for the major indoor contaminants.

Someday instrumentation will be available that can be installed in school buildings that will continuously monitor the air for various contaminants and notify the occupants when the concentrations exceed the safe levels. This type of equipment is presently available for pollutants found in manufacturing environments such as to detect concentrations of carbon monoxide.

Figure 4.1

Control techniques for indoor air contaminants

Descriptive Summary	Control Techniques
RESPIRABLE SUSPENDED PARTICLES (RSP):	
Particles or fibers in the air small enough to be inhaled. RSP is a broad class of chemically and physically diverse substances. Tobacco smoke is usually the largest indoor source. Other sources include fireplaces, wood astoves, unvented gas appliances, kerosene heaters, asbestos construction material, house dust.	- Avoid smoking tobacco indoors - Be sure woodstove doors and flues do not leak - Vent combustion appliances outdoors - Supply outdoor air directly to woodstove and fireplace firebox - Effectiveness of air cleaning devices varies widely. Electrostatic precipitators and high efficiency (HEPA) filters are most effective. - Change air filters regularly.
COMBUSTION GASES: Carbon monoxide (CO) and nitrogen dioxide (NO_2) are gases formed during the use of gas stoves, unvented gas & kerosene space heaters and wood stoves. Tobacco smoke is another source. CO increases when there is an inadequate supply of combustion air; No2 increases with higher combustion temperature	- Pay attention to operating & maintenance instructions on space heaters. Improper wick length or air shutter tuning can effect CO & NO_2 emissions. - Choose a properly sized wood stove or space heater to heat your home. - Maintain adequate ventilation. Use local ventilation i.e., vented range hoods on gas stoves, when possible.
ALLERGENS AND PATHOGENS: A wide variety of bacteria, viruses, fungi, pollen, algae, etc., which can product infection, disease or allergic reaction. Major sources are human activity and domestic animals. Excessive humidity,	- Maintain low relative humidity levels - Eliminate any stagnant water associated with humidifiers, air conditioning equipment, saunas, etc.

(figure continues)

Figure 4.1

Control Techniques for Indoor Air Contaminants

Descriptive Summary	Control Techniques
standing water, redcuced ventilation and use of untreated recirculating air can increase concentrations of microorganisms.	- Air cleaning devices may remove microorganisms and allergens. Filters should be cleaned frequently.
RADON: A naturally occurring radioactive gas which enters homes primarily from underlying soil and rock. Other sources include drinking water and building materials.	- Seal off pathways between the soil or crawl space and outdoors - Ventilate soil to draw radon gas away from home - Ventilate crawl space - Overpressurize basement to inhibit radon entry - Increase air exchange in tight rooms - Air cleaning under study
FORMALDEHYDE: A strong smelling water-soluble gas used as a component of some insulation and of adhesives used in making plywood, particle board and fiberboard. Other sources include furniture, drapes, carpet, paper products.	- Use "low fuming" formaldehyde products - Seal or treat surfaces to reduce emissions - Maintain low indoor humidity levels - House, ventilation, air cleaning, ammonia fumigation under study.
ORGANIC COMPOUNDS: A wide variety of chemicals used in household products (Cleaners, paints, aerosols, deodorizers), pesticides, building materials, and furnishings. Also released by smoking and gas or wood burning appliances.	- Pay attention to warning & instructions for storage and use - Use only in well ventilated areas - Substitute less hazardous products, e.g., use of a liquid or dry form of a product vs. an aerosol spray

NOTE. From Indoor Air Quality Environmental Information Handbook (Contract No. DE-AC01-81EV10450) (pp. 2.2-2.3) United States Department of Energy, 1987, Washington, D.C.

APPENDICES

Appendix A

Terminology

ACH--Abbreviation for "air changes per hour," a unit of air exchange rate.

Absorption--Removal of contaminants from the air by soaking them into a material.

Active Monitoring Device--Monitoring equipment which requires an external source of power to operate.

Acute--Category of illness caused by indoor air pollution which will cause death.

Absorption--Removal of contaminants from the air by their retention on the surface of a material.

Air Cleaner--A device designed to remove airborne pollutants such as dust and smoke.

Air Exchange Rate--Amount of air that flows into or out of a building in a specified amount of time.

Air-To-Air Heat Exchangers--Mechanical ventilation devices which can be used to conserve energy.

Aldehydes--Series of organic-based compounds containing -CHO groups and having strong orders.

Allergens--A diverse group of substances that cause allergic reactions.

Allergic--Highly susceptible to a substance that does not produce harmful health effects in a majority of the population.

Ambient Air--That portion of the air that is external to the building.

Analyzer Monitoring Device--Monitoring device which also analyzes the sample being monitored along with providing the results of the analysis.

ASHRAE--Abbreviation for "American Society of Heating, Refrigerating and Air Conditioning Engineers."

Building Envelope--The exterior surfaces such as walls, floor and roof which enclose a building.

Carbon Dioxide--Colorless, odorless gas that is the product of metabolic activity and combustion.

Carbon Monoxide--Colorless, odorless gas that is the product of incomplete combustion process.

CFM--Abbreviation for "cubic feet per minute."

Charcoal Canister--A passive monitoring device for radon.

Chronic--Category of illness from indoor air pollution that continues to exist for a long time and if not alleviated will result in acute illness.

Ci--Abbreviation for "Curie," a unit of radioactivity equal to 37 billion disintegrations per second.

Clearance Rate--Time it takes for the body to get rid of a pollutant.

Collector Monitoring Device--A type of monitoring device that only collects a sample of air. It must then be sent to a laboratory for analysis.

Concentration--Amount of contaminant in a given volume of air.

Conduction--Movement of heat through a material by molecular vibration.

Contaminant--Substance in the air that is not normally present or that is present in greater-than-normal concentration.

Convection--Movement of fluids (gases and liquids) in response to differences in density caused by temperature differences.

Criteria Pollutants--Pollutants for which there exists national acceptable standards.

Depletion--To reduce the concentration of a pollutant.

Detoxification--To remove toxic substances from the body.

Diffusion--Spontaneous scattering of particles throughout the air from areas of high concentration to areas of low concentration.

Dispersion--Movement of contaminants throughout the air by dispersion and mixing.

Dose--Quantity of a substance absorbed in a part of the body or in an individual.

Electronic Digital Hygrometer--A battery-operated device which measures temperature and relative humidity.

Electrostatic Interaction--Mutual attraction of materials that have opposite electrical charges.

Electrostatic Precipitation--Removal of particles from the air by attracting them to charged materials.

Emission Rate--Amount of contaminant released into the air by a source in a specified amount of time.

Encapsulation--Covering of an object with a film or coating to prevent release of air contaminants from the object.

EPA--Abbreviation for "Environmental Protection Agency," the federal agency responsible for setting and enforcing ambient air quality standards.

Epidemiology--The study of disease as it spreads and involves large groups of people.

Exfiltration--Uncontrolled movement of air out of a building through cracks in the building envelope.

Filtration--Removal of particles from the air by passing the air through a material that screens out the particles.

Forced Ventilation--Ventilation induced by use of mechanical equipment such as exhaust fans.

Formaldehyde--Common air contaminant emitted from many synthetic materials.

$\mu g/m^3$--Abbreviation for "microgram per cubic meter," a measure of mass per unit volume.

Hypersensitive--High susceptibility to a substance that does not produce harmful health effects in a majority of the population.

Impervious--Impenetrable.

Indicator Tubes--Chemically treated glass tubes which discolor when exposed to a specific pollutant.

Infectious Agents--Bacteria, viruses, and microorganisms that cause human disease.

Infiltration--Uncontrolled movement of air into a building through cracks in the building envelope.

Inhalable Particles--Particles that are not filtered out by the nose and that are deposited along the respiratory tract.

Insecticide--A chemical compound or substance used to kill insects.

Make-up Air--Outdoor air, sometimes called fresh air.

Mass-Balance Approach--Method of studying the change in concentrations of contaminants in the air by measuring rates of contaminant emission and removal.

Mechanical Filtration--Filtering of air by the use of mechanical equipment such as electronic air filters.

Mechanical Ventilation--Forced movement of air by fans into and out of a building.

Mitigation--Removing air pollutants.

Mixing--Redistribution of particles by movement of air.

Natural Ventilation--Movement of air into and out of a building through openings in the building envelope.

NIOSH--Abbreviation for the "National Institute of Occupational Safety and Health."

Noncriteria Pollutants--Pollutants for which there does not exist nationally-accepted standards.

Organic Compounds--Substances which contain carbon.

Outgas--Emission of gases during the aging and degradation of a material.

Passive Monitoring Device--Monitoring equipment which does not need an external source of power to operate.

pCi/L--Abbreviation for "picocuries per liter of air," a measurement of radon concentration.

Permeability--A characteristic of a material which relates to the flow of gasses or liquids through it.

Pesticide--Chemical compound or substances which is used to control rodents and insects.

Plating--Settling out of particles onto a material.

Pollutant--Contaminant present in a concentration high enough to cause adverse effects to health or the environment.

Pollution--The occurrence of one or more contaminants in concentrations high enough to cause adverse effects to health or the environment.

PM--Abbreviation for "parts per million," a unit of concentration.

Radon--Chemically inert gas that undergoes radioactive decay by emission of an alpha particle.

Radon Daughters--A series of radioactive elements that result from the radioactive decay of radon.

Radon Progeny--Series of elements that result from the radioactive decay of radon.

Removal Mechanism--Object or process that removes contaminants from the air.

Removal Rate--Amount of contaminant removed from the air by a removal mechanism per unit of time.

Respirable Particles--Particles that penetrate to the lungs when inhaled.

Sensidyne Gastec Pump--A brand name of a pump used with indicator tubes to measure concentrations of certain pollutants.

Spot Ventilation--Mechanical ventilation located at a specific place such as an exhaust fan over a gas stove.

Suspended Particles--Particles so small that they remain in the air and settle out slowly under the force of gravity.

Threshold Level--Concentration above which one's health is affected by a specific contaminant.

Toxic--Capability of a substance to produce a harmful health effect after physical contact, ingestion or inhalation.

Toxicology--Study of the health-related affects of toxic substances.

Ventilation--Controlled movement of air into and out of a building.

WL--Abbreviation for "working level," a unit of radon progeny concentration.

Working Level--Unit of radon progeny concentration.

Appendix B

COMPREHENSIVE BUILDING SURVEY FORM

INTRODUCTIONS:

Using this form, additional blank paper (if needed), appropriate instrumentation and the completed Health Information Form, tour and inspect the building and its support system(s) beginning on the outside of the building and then the inside. Use one form for each building. Circle the appropriate response and/or record all information requested in the form. If not applicable, so note with a N/A or leave blank.

Part I. General Information

Building Name____________________ Age of Building____________________

Name of Inspector__________________ Date of Inspection__________________

Time of Inspection__________________ Pres____________to________________

Are construction drawings and specifications available for this building?
Yes No

Part II: Building Exterior--General

Describe where the building is located in terms of the surrounding area (i.e., residential area, rural area).

____

____

____

Do the following exist?

Landfill within 1 mile of building?	Yes	No
Smoke stack industry within 1 mile of building?	Yes	No
A creek or other open body of water adjacent to the building?	Yes	No

Record any specific comments on the above three questions and/or provide any other sources of pollutants which are observed outside the building.

____

____

____

Rate the overall quality of the air by taking some deep breaths and note any odors:

Excellent Good Average Below Average Poor

Odor(s)____

Type of Building Foundation

Wall and Columns on Footings Slab on Grade

Other____________________________

Are there one or more garages attached to the building? Yes No

If yes, explain what activities occur in them and what spaces (in terms of use) immediately adjoin them?

____

____

____

____

Part III: Building Exterior--Materials

For the following building exterior elements note the type of material(s) of which each is constructed and rate the level of condition it is in.

Walls ____________________

Good Condition and Clean	Good Condition But Needs Cleaning	Poor Condition and Needs Repair

Special Comments on Walls:

____

____

____

____

Doors ____________________ and Frames ____________________

Good Condition and Clean	Good Condition But Needs Cleaning	Poor Condition and Needs Repair

Special Comments on Doors:

____

____

____

____

Windows ____________________ and Frames ____________________

Good Condition and Clean	Good Condition But Needs Cleaning	Poor Condition and Needs Repair

Special Comments on Windows

____

____

____

____

Roof(s)____

Good Condition and Clean	Good Condition But Needs Cleaning	Poor Condition and Needs Repair

Special Comment on Roof(s):

What is the general condition of any coatings such as paint?

Good (Does not need attention)	Average (Will need attention soon)	Poor (Needs immediate attention)

Special comments on the condition of coatings:

Does there exist any devices which are attached to and project out from the building such as chimneys, vents, etc. Yes No

If yes, describe each and rate what condition they are in?

What kind of insulation exists in the exterior building walls?

F Describe any other items or activities on the building exterior which you feel may contribute to poor indoor air quality?

____
____
____
____
____
____
____

Part IV: Building Interior--General

How many levels occur within the building (including basement)?________

Which of the following building spaces exist:
Basement Crawl Space Attic?

Does a cafeteria exist in the building? Yes No

If there is not a cafeteria in the building, where do the building occupants eat their meals:

____
____
____

What is the source of the drinking water in the building?

____
____
____

Where does the waste water from the building go to?

Septic Tank Waste Treatment Plant Body of Water

Is there any asbestos in the building? Yes No

If yes, where?

____
____
____

Is smoking allowed in the building? Yes No

If yes, where and has special ventilation been provided?

Has there been any building renovations made within the last two years? If so, describe them.

Has an energy conservation program been implemented within the past two years? If so, describe what it entailed.

Part V: Building Interior--Materials

Using the Room Inspection Form, inspect the rooms in the building where sources and/or causes of indoor air pollutants are suspected (this may include all the rooms). Pay particular attention to rooms containing equipment, laboratories, chemical storage and typical classroom activities. Complete one form for each room.

Part VI: Building HVAC System

Present a brief description on how the building is heated and cooled (provide the type and manufacture of the system[s]).

P Provide the location of any intake makeup air vent(s), relative to the location of any air exhaust vent(s) (be as specific as possible).

Type of Air Handling System: Variable Volume Self-Contained
Constant Volume Other__________

How is heat brought to each room? Water Air Other__________

Is there a central cooling system? Yes No

How is cooling brought to each room? Water Air Other__________

The heating system is powered by: Electricity Gas Coal Oil

The central cooling system is powered by Electricity Gas Coal Oil

Approximate age of any central heating/cooling equipment:____________

Appearance of any central equipment:

Appearance of any air filters in central unit(s): Good Average Poor

Appearance of any water filters in central unit(s): Good Average Poor

If water is used in the system is it treated with any chemicals? Yes No

If yes, state the chemical type, and how often it is used and in what quantities?

Are there window air conditioning units? Yes No

If yes, approximately what percent of the total number of rooms have window units?____________________%

Appearance of window units: Good Average Poor

Appearance of window unit filters? Good Average Poor

How is the temperature controlled in the building?

Overall condition of mechanical (furnace) room: Good Average Poor

State any condition(s) such as standing water, which is seen in the room which may have an effect on the quality of air:

How is the water heated for tap hot water? Electricity Gas Coal Oil

What is the condition of the hot water heater? Good Average Poor

Provide any other information about the condition of the central and/or local HVAC system(s) which may have a bearing on the quality of the indoor air:

Part VII: Building Maintenance

Are any of the following substances used? If so, where and when?

Liquid Cleaners:

Powder Cleaners:

Rug Cleaners: ______________________

Room Deodorizers: ______________________

Floor Stripping Compounds: ______________________

Floor Waxes: ______________________

Paints: ______________________

Insecticides: ______________________

Pesticides: ______________________

Other (   ): ______________________

When is the building cleaned (state time of day):______________________

How often is the building cleaned?______________________

Where are all the various cleaning agents and other maintenance chemicals stored?

____

____

____

Is the storage area accessible to students: Yes No

Yes No

Provide any other data about the general building maintenance which you feel may have a bearing on the quality of the indoor air?

____

____

____

____

____

____

Part VIII: Summary of Physical Measurements Taken During Inspection

Temperature: (Instrument[s] Used):______________________

Average Temperature of All Room(s):_______________ °F

Relative Humidity: (Instrument[s] Used):_______________

Averate Relative Humidity of all Room(s):_______________ °F

All Materials: For each substance material, state the structure, device(s) used for monitoring and the averse laboratory results for all rooms monitored:

1. Pollutant:_______________

   Device(s) used:_______________

   Average Laboratory Results:_______________

2. Pollutant:_______________

   Device(s) used:_______________

   Average Laboratory Results:_______________

3. Pollutant:_______________

   Device(s) used:_______________

Average Laboratory Results:

4. Pollutant:

Device(s) used:

Average Laboratory Results:

5. Pollutant:

Device(s) used:

Average Laboratory Results:

Provide any general comments relating to the taking of physical measurements which may effect the quality of the indoor air:

Review the Indoor Air Quality Health Information Form with the Principal (and other appropriate personnel) to clear up any questions, and attempt to determine the causes of the reported acute illness symptoms and sensory items. Furthermore identify if the symptoms are related to a specific area of the building, occur at a specific time of the day, etc. Also record the persons' perceptions of the overall quality of the air in the building in general.

Names and Titles of People Interviewed:

Provide any final comments relating to the quality of the indoor air, sources, effects, etc.

ROOM INSPECTION FORM

Instructions: Using a separate form for each room, tour the facility and provide responses to all the questions. Also provide any special information which may have a bearing on the quality of the air in the room.

Room Designation ______________________________

Level of Building ______________________________

Specify the activities which occur in the room ______________________________

____

____

Specify the types of materials of which each of the following is comprised and the condition of each in terms of appearance and cleanliness.

Wall Construction: ______________________________

Wall Finish: ______________________________

Condition of Wall: Good Fair Poor

Floor Construction: ______________________________

Floor Finish: ______________________________

Condition of Floor: Good Fair Poor

Ceiling Construction: ______________________________

Ceiling Finish: ______________________________

Condition of Ceiling: Good Fair Poor

Answer the following questions if appropriate:

Are there any water stains on any of the surfaces? Yes No

Room ______________________

If yes, where are they located and what appears to be the cause? ____________
____
____

Is there any mold or mildew on any of the surfaces? Yes No

If yes, where is it located and what appears to be the cause? ____________
____
____

Are there any odors in the room? Yes No

If yes, describe the odor, its cause(s), and its intensity. ____________
____
____

If any of the following exist respond to the questions presented for each:

Kerosene Space Heater(s):
  Special ventilation provided: Yes No
  Condition: Good Fair Poor

Natural Gas Heater(s):
  Special ventilation provided: Yes No
  Condition: Good Fair Poor

Gas Stove(s):
  Special ventilation provided: Yes No
  Condition: Good Fair Poor

Room Air Conditioning Unit(s)
  Condition: Good Fair Poor
  Condition of filter:: Good Fair Poor

Humidifier(s):
  Condition: Good Fair Poor

Dehumidifier(s):
  Condition: Good Fair Poor

Room ____________________

Air Cleaner(s):
Condition: Good Fair Poor
Condition of filter: Good Fair Poor

Wall, Ceiling and/or Floor Air Vents:
Condition: Good Fair Poor

Plumbing Pipes and/or Fixtures (indicate type and condition of each)________
____
____
____

Lights and Fixtures (indicate type and condition of each)________________
____
____
____

Do you feel the intensity of lighting is appropriate for what is going on in the room? Yes No

Note any other mechanical, electrical, plumbing device or any other item in the room which may be a source of indoor pollutants such as a microwave oven, laboratory equipment, and state the condition of each.

____
____
____
____
____
____
____
____
____

Is there a copying machine in the room? Yes No

Has special ventilation been provided? Yes No

If yes, state type and its condition:______________________
____
____
____

Room ____________________

Are there any chemicals stored in the room or in rooms that open into this room? If so, indicate the type of chemical(s) and for what they are used.

State any activities which occur in the room which you feel may effect the air quality in the room.

How is the temperature controlled for this room?____________________

Rate how you feel the temperature is:	Cold	Acceptable	Hot

Record the temperature:____________________

Rate how you feel the quality of air is:	Stale	Acceptable	Fresh
Rate how you feel the humidity is:	Dry	Acceptable	Humid

Record the relative humidity:____________________

Rate the general comfort of the room:	Drafty	Acceptable	Stuffy

Describe the types of interior room furnishings and of what material they are constructed:

Room ____________________

Monitoring of Air in Room:

Note the pollutant and the results for each one monitored:

1. Pollutant Name: ____________________

   Results: ____________________

2. Pollutant Name: ____________________

   Results: ____________________

3. Pollutant Name: ____________________

   Results: ____________________

4. Pollutant Name: ____________________

   Results: ____________________

Room ______________________

5. Pollutant Name: ______________________

Results: ______________________

Provide any other comments which will aid in analyzing whether any activities, materials, and/or equipment exist which are potential sources of indoor air contaminants:

Companies Which Provide Monitoring and Analytical Services for Indoor Air Pollutants

Company and Address	Telephone				PARTICLES		ORGANICS				BIOAEROSOLS	
		Formaldehyde	Nitrogen Oxides	Carbon Monoxide	Asbestos	Airborne Particles	Particle Phase Organics	Volatile Organics	Pesticides	PCBs	Microorganisms	Aeroallergens
Advanced Chemical Sensors Company 350 Oaks Lane Pompano Bach, FL 33069	(305) 979-0958	●	●	●				●	●			
AeroVironment, Inc. 825 Myrtle Avenue Monrovia, CA 91016	(818) 357-9983	●	●	●	●	●	●	●			●	●
AeroVironment, Inc. 8505 Delmar Blvd. St. Louis, MO. 63124	(314) 993-0543	●	●	●	●	●	●	●			●	●
Applied Technology Consultants 1800-B, Airport Road Opelika, AL 36801	(205) 749-6366	●	●	●	●	●	●	●	●	●		
Arthur D. Little, Inc. Acorn Park Cambridge, MA 02140	(617) 864-5770	●	●	●	●	●	●	●	●	●	●	●
Batta Environmental Associates P.O. Box 9722 Newark, DE 19714	(302) 737-3376		●	●	●	●		●	●	●	●	

Companies Which Provide Monitoring and Analytical Services for Indoor Air Pollutants (Continued)

Company and Address	Telephone				PARTICLES		ORGANICS				BIOAEROSOLS	
		Formaldehyde	Nitrogen Oxides	Carbon Monoxide	Asbestos	Airborne Particles	Particle Phase Organics	Volatile Organics	Pesticides	PCBs	Microorganisms	Aeroallergens
Bio-Technics Laboratories, Inc. 1133 Crenshaw Boulevard Los Angeles, CA 90019	(213) 933-5991	●	●	●	●	●		●	●	●	●	
California Analytical Laboratories Inc 2544 Industrial Boulevard West Sacramento, CA 95691	(916) 372-1393							●	●	●		
Concord Scientific Corporation 2 Tippett Road Downsview (Toronto), Ontario Canada M3H 2V2	(416) 630-6331	●	●	●	●	●	●	●	●	●	●	●
Continental Environment Co., Inc. 34 Maple St. Summit, NJ 07901	(201) 277-2255	●	●	●								
Cooper Engineers, Inc. 1301 Canal Boulevard Richmond, CA 94805	(415) 235-2360	●	●	●	●	●	●	●	●	●		

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Companies Which Provide Monitoring and Analytical Services for Indoor Air Pollutants (Continued)

Company and Address	Telephone				PARTICLES		ORGANICS				BIOAEROSOLS	
		Formaldehyde	Nitrogen Oxides	Carbon Monoxide	Asbestos	Airborne Particles	Particle Phase Organics	Volatile Organics	Pesticides	PCBs	Microorganisms	Aeroallergens
CTEX 9742 Skillman Dallas, TX 75243	(800) 527-2835	●	●	●	●	●		●	●	●		
CTL Environmental Services 2905 E. Century Boulevard South Gate, CA 90280	(213) 564-2641	●	●	●	●	●	●	●	●	●		
Demaray Scientific Instruments, Ltd. S.E. 1122 Latah Street Pullman, WA 99163	(509) 332-8577	●		●				●	●			
Douglas P. Fowler 415 Cambridge Avenue, Suite 11 Palo Alto, CA 94306	(415) 321-7610	●	●	●	●	●	●	●	●	●		
EAL Corporation 2030 Wright Avenue Richmond, CA 94804	(415) 235-2633	●	●	●	●	●	●	●	●			
Fireman's Fund Risk Management Services, Inc. P.O. Box 15065 Sacramento, CA 95825	(916) 924-4519	●	●	●	●	●	●	●	●	●		

Companies Which Provide Monitoring and Analytical Services for Indoor Air Pollutants (Continued)

Company and Address	Telephone				PARTICLES		ORGANICS				BIOAEROSOLS	
		Formaldehyde	Nitrogen Oxides	Carbon Monoxide	Asbestos	Airborne Particles	Particle Phase Organics	Volatile Organics	Pesticides	PCBs	Microorganisms	Aeroallergens
Galson Technical Services, Inc. 1435 167th Avenue #44 San Leandro, CA 94578	(415) 481-2379	●	●	●	●	●	●	●	●	●	●	
GCA Corporation Technology Division 213 Burlington Road Bedford, MA 01742	(617) 275-5444	●	●	●	●	●	●	●	●	●		
Home Testing Labs & Decontamination Corporation 299 W. Fort Lee Road Bogota, NJ 07603	(201) 343-1199	●	●	●	●	●	●	●	●	●	●	●
Honeywell, Inc. 1985 Douglas Drive Golden Valley, MN 55422	(612) 542-6569	●	●	●		●		●	●			
IHI-Kemron 755 New York Avenue Huntington, NY 11743	(516) 427-0950	●	●	●	●	●			●			
INA Loss Control Services, Inc. 1021 Georgia Avenue Macon, GA 31201	(800) 841-8919	●	●	●	●	●	●	●	●	●		

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Companies Which Provide Monitoring and Analytical Services for Indoor Air Pollutants (Continued)

Company and Address	Contact and Telephone				PARTICLES		ORGANICS				BIOAEROSOLS	
		Formaldehyde	Nitrogen Oxides	Carbon Monoxide	Asbestos	Airborne Particles	Particle Phase Organics	Volatile Organics	Pesticides	PCBs	Microorganisms	Aeroallergens
Independent Asbestos Labs, Inc. 5900 Butternut Drive East Syracuse, NY 13057	(315) 437-1122				●							
Interpoll, Inc. 4500 Ball Road, N.E. Blaine, MN 55014	(612) 786-6020	●	●	●	●	●	●	●	●	●	●	●
IT Corporation 17605-D Fabrica Way Cerritos, CA 90701	(213) 921-9831	●		●	●	●	●	●	●	●		
J.M. Cohen, Inc. 8261 E. Hillsdale Boulevard, Suite 2 Foster City, CA 94404	(415) 349-9737			●	●	●				●		
John F. Summersett 1432 Jocasta Drive Lexington, KY 40502	(606) 273-8881			●	●						●	
Kenneth S. Cohen Consulting Health Services Division of TOXOS Corporation P.O. Box 1625 El Cajon, CA 92022	(619) 579-6233	●	●	●	●	●		●			●	●

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Companies Which Provide Monitoring and Analytical Services for Indoor Air Pollutants (Continued)

Company and Address	Contact and Telephone				PARTICLES		ORGANICS				BIOAEROSOLS	
		Formaldehyde	Nitrogen Oxides	Carbon Monoxide	Asbestos	Airborne Particles	Particle Phase Organics	Volatile Organics	Pesticides	PCBs	Microorganisms	Aeroallergens
Med-Tox Associates, Inc. 1401 Warner, Suite A Tustin, CA 92680	(714) 669-0620	●	●	●	●	●	●	●	●	●	●	
Microbac Laboratories 2401 West 26th Street Erie, PA 16506	(814) 833-4790	●	●	●	●	●			●	●	●	
NHS, Inc. 805 Goethals Drive Richland, WA 99352	(509) 943-0802	●	●	●	●	●	●	●	●	●		
Occupational Health Department of Health Services 225 37th Avenue San Mateo, CA 94403	(415) 573-2798	●	●	●	●	●		●	●	●	●	
Penn State University 227 Grange Bldg. University Park, PA 16802	(814) 865-6391	●		●	●			●			●	
Princeton Testing Laboratory P. O. Box 3108 Princeton, NJ 08540	(609) 452-9050	●		●		●		●			●	

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Companies Which Provide Monitoring and Analytical Services for Indoor Air Pollutants (Continued)

Company and Address	Contact and Telephone				PARTICLES		ORGANICS				BIOAEROSOLS	
		Formaldehyde	Nitrogen Oxides	Carbon Monoxide	Asbestos	Airborne Particles	Particle Phase Organics	Volatile Organics	Pesticides	PCBs	Microorganisms	Aeroallergens
Safety Specialists, Inc. P.O. Box 4420 Santa Clara, CA 95054	(408) 988-1111	●	●	●	●	●	●	●	●	●	●	●
SRI International PS167 Pnysical Chemistry Department 333 Ravenwood Avenue Menlo Park, CA 94025	(415) 859-4515	●	●	●	●	●	●	●	●	●	●	●
St. Paul Risk Services 494 Metro square Bldg. St. Paul, MN 55101	(612) 221-8020	●	●	●	●	●	●	●	●	●		
Theodor D. Sterling, Ltd. #70-1507 W. 12th Avenue Vancouver, B.C. Canada V6J 2E2	(604) 733-2701	●	●	●		●		●				
Thomas J. Walker, Inc. 1678 Lower Grand Avenue Piedmont, CA 94611	(415) 652-7847	●	●	●	●	●	●	●	●	●	●	●
Thomas Pierce Department of Chemistry University of North Alabama Florence, AL 35630	(205) 766-4100		●	●	●	●		●	●	●		

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Companies Which Provide Monitoring and Analytical Services for Indoor Air Pollutants (Continued)

Company and Address	Contact and Telephone				PARTICLES		ORGANICS				BIOAEROSOLS	
		Formaldehyde	Nitrogen Oxides	Carbon Monoxide	Asbestos	Airborne Particles	Particle Phase Organics	Volatile Organics	Pesticides	PCBs	Microorganisms	Aeroallergens
Traveler's Insurance Company Engineering Division 8ST Hartford, CT 06155054	(208) 277-6031	●	●	●	●	●	●	●	●	●		
W.S. Flemming & Associates, Inc. 5802 Court Street Road Syracuse, NY 13206	(315) 437-1780	●	●	●		●	●					
Western Environmental Services 1010 South Pacific Coast Highway Redondo Beach, CA 90277	(213) 540-4676		●	●		●		●		●		
Geomet Technologies 20251 Century Blvd. Germantown, MD 20874	(301) 428-9898	●	●	●	●	●	●	●	●	●	●	●

NOTE: From Indoor Air Quality Environmental Handbook: Building Characteristics (Contract No. DE-AC-1-81EV10450) (pp. 4-46-4-53) United States Department of Energy, 1987, Washington, DC

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Appendix E

References on Indoor Air Pollution

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